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REPORTS OF OBSERVATORIES 1958–1959

Allegheny Observatory, University of Pittsburgh, Pittsburgh, Pa.

Thaw Refractor. The very poor observing conditions of the previous year continued this year so that an even smaller number of plates, 967, resulted for the astrometric programs. The 45-year total stands at 91,660. Plates were obtained on only 95 nights. There were 84 evenings, and 41 mornings, when observations were made. Both evening and morning observations were made on 30 nights. The telescope was in use 275 hours which is about half of normal. Observers were Wagman, and amateur astronomers R. J. Creek, W. A. Feibleman, W. K. Hartmann, R. F. Kemper, Dr. J. F. Kunze, D. J. Peart, R. L. Scherer, J. F. Schwartz, Jr., G. F. Swetnam, Jr., and G. A. Winterhalter.

Mrs. Crissman measured 747 plates and finished 16 parallaxes. She has a list of 55 ready for publication. Measurements of Altair and Luyten 726–8 by Wagman, BD + 4°4048 by Hartmann, and Ross 808 by Beth Beyer, involved 152 other plates. Ross 808 is a 14th magnitude suspected white dwarf.

Keeler Telescope. Kiewiet de Jonge and Beardsley have brought the development and testing of the Keeler telescope and Mellon spectrograph to the point where the program of observation of radial velocities of spectroscopic binaries has been started. This year's program has involved a new console, input wiring, a new slow motion, and installation of optics for producing the comparison spectrum. The main chassis of the integrating exposure meter for the spectrograph is essentially complete. A new dark room with new equipment has been put into operation. A projection comparator for measuring the spectra is under construction in the Observatory shop. Support for this work has been received from the National Science Foundation.

Miscellaneous. K. B. Adams, Westinghouse Research Laboratories, is continuing the work on hollow cathode spectra of *Cu*II, *Ne*II, and *Ne*I which he and Burns were collaborating in until Burns' death last year. He has developed a better source for producing sharper weak lines. The *Ne*II is being arranged in manuscript form.

There were 76 students in the two undergraduate courses offered by Kiewiet de Jonge and Wagman at the University. Kiewiet de Jonge had 26 students in a one semester course at Chatham College. He also lectured in the History and Philosophy of Science course there.

Night visitors totalled totalled 3793 for the 147 public evenings. Lecturers were Kemper, Kunze, Peart, and Swetnam. Day visitors numbered 2644. The 13-inch Fitz refractor, now in its 100th year is used in the endowed program for evening visitors begun by John A. Brashear 50 years ago.

A Questar portable telescope, the gift of Mrs. Alan M. Scaife, proved to be very useful for giving visitors views of the sun. Dr. J. Allen Hynek spent two days on campus in the "Program of Visiting Astronomers".

N. E. WAGMAN, *Director*

David Dunlap Observatory, University of Toronto, Richmond Hill, Ont.

Personnel. Dr. Sidney van den Bergh has been promoted to Assistant Professor. Dr. William Buscombe of Mount Stromlo Observatory visited here from October until December, 1958, assisting with the teaching in the Department of Astronomy and taking part in research at the

Observatory. Dr. Leonard Searle spent two summer months in 1959 at the California Institute of Technology.

Radial Velocities. Appreciable progress has been made in the observations and measurements for several programs reported earlier, particularly a program of stars in areas near the Kapteyn Areas and a program of faint OB stars.

Spectrographic Binaries. Miss Northcott has obtained observations for orbit determinations of HD 19485 and 174369. Heard has discovered a double-lined binary of large mass in the Cepheus III aggregate, namely HD 217312.

Photometric. Bakos has completed an evolutionary interpretation of 75 visual binary systems from photometric and luminosity data which he had obtained. Dr. Helen Hogg has continued her studies of David Dunlap photographs for variables in globular clusters.

Stellar Spectra. MacRae has obtained measures of the total absorption of $H\gamma$ for 70 early-type stars, using the photoelectric spectrophotometer. Searle has completed an analysis of Mount Wilson high dispersion spectrograms of R Coronae Borealis, determining the abundances of hydrogen, carbon and the metals relative to the abundances in δ Canis Majoris. In this connection he has made theoretical studies of opacity sources in hydrogen-poor stars. Searle has also commenced a high-dispersion analysis of the early-type carbon stars HD 187040 and 156074 with the intention of following up questions raised by the analysis of R Coronae Borealis.

Planetary Spectra. Heard has studied the spectrum of Jupiter in the photographic region with a view to investigating further the absorption recently reported by Kiess, Corliss and Kiess. When the Jupiter spectrum is compared to the moon's, there is some suggestion of two regions of absorption at wave-lengths 4800A and 4500A as well as general absorption increasing towards shorter wave-lengths.

Radio Astronomy. Standards of noise power have been developed at 77°K and 1000°K to be used in absolute flux measurements of the sun and the brighter radio sources. A parametric amplifier has been built for use at 320 Mc/sec. The properties of certain types of antennas for use as elements in arrays is under investigation. These projects are being directed by MacRae with the active cooperation of the Department of Electrical Engineering.

External Systems. van den Bergh has developed a luminosity classification system for galaxies of types Sb, Sc and Ir. Using this system it is possible to estimate the absolute magnitude of a galaxy with an accuracy of 0.5 magnitudes from the prints of the Palomar Sky Survey. A catalogue has been completed which contains the Hubble type, luminosity class and angular diameter of all Shapley-Ames galaxies north of $\delta = -27°$. Using the material contained in the catalogue it has been possible to isolate a large cluster of relatively nearby galaxies in Canes Venatici. The cluster has a true distance modulus of 28.2 ($H = 100$ km/sec/Mpc) and contains predominantly late type galaxies. The cluster also shows up well in a catalogue of dwarf galaxies north of $\delta = -23°$ which has recently been published. The mass of the Canes Venatici cluster, as determined from the virial theorem, exceeds the total mass of the cluster galaxies by at least an order of magnitude.

Stellar Models. Demarque has constructed sequences of models for homogeneous stars of different compositions. Model atmospheres were constructed to provide realistic boundary conditions for the interior integrations. The principal result is that the main sequence of extreme population II stars does not deviate by more than three tenths of a magnitude in the theoretical H-R diagram from the main sequence of stars of solar composition for any plausible assumptions concerning population II abundances. The computations were performed on the University of Toronto IBM 650 computer.

Instruments. A grant has been received from the National Research Council of Canada for the construction of a grating spectrograph with Schmidt cameras for the 74-inch telescope. The proposal is to design the spectrograph to include dispersion as high as 10 Å/mm.

Bibliographical. Dr. Helen Sawyer Hogg completed the comprehensive article on Star Clusters which appeared in Vol. 53 of the *Handbuch der Physik*, and published a summary of current research on variables in globular clusters in the report of sub-commission 27b of the I.A.U. She also prepared a survey article on variable stars in star clusters (*J. R. Astr. Soc. Can.* **53**: 97, 1959). The first supplement to her "Bibliography of Individual Globular Clusters" is well along in preparation for publication.

JOHN F. HEARD, *Director*

Dudley Observatory, Albany, N. Y.

Personnel: Dr. Hugh Bowman has been appointed a research associate of Dudley Observatory.

Educational and Cultural Program: To help the Observatory meet the intense educational and cultural demands created by the space age, the Friends of the Observatory has been formed. The membership is 211 at present. Friends' funds have been used to install seating in the telescope dome, purchase a number of astronomical films, slides and books, a large astronomical globe and other astronomical instructional aids. It is hoped that the Friends of the Observatory will provide for Dudley Observatory the encouragement, enthusiasm and support given to other components of the University by their alumni.

The Tuesday public open nights and the program of special lectures and viewings for club, scout and school groups have been continued. Since September 1956, 6,277 visitors have come to the Observatory.

The Albany Amateur Astronomy Club continues to meet bimonthly at the Observatory. A room has been set aside for the club use in the Observatory basement.

The extension school course in astronomy offered in cooperation with the New York State College for Teachers was taught again this year by Professor Pryor to 22 local science teachers. Next year the course will be open to area college students and 29 students have already registered.

The Albany County Committee for the Hudson Champlain Celebration held in New York State during 1959 has elected to erect a planetarium adjacent to the Observatory as a permanent living memorial for this year-long celebration. This planetarium, to be known as the Henry Hudson Planetarium, will be operated for the community by Dudley Observatory as a part of its educational and cultural program. Princess Beatrix of Holland will participate in a ground breaking ceremony to be held on September 19, 1959.

Research Program: The Air Force Cambridge Research Center has awarded Dudley Observatory a contract which will permit the Observatory to expand its program of collecting and studying high altitude airborn particles with the hope of identifying and studying micrometeorites. A dust-free laboratory has been constructed in the Observatory basement to house a small electron microscope and other instruments used for these studies. Mr. Fullam and the Director will present a paper concerning this research program at the meeting of the American Meteoritical Society on September 11, 1959.

The search for meteoric bombardment of the dark side of the moon was continued this year by Mr. Monte Holland and Mr. Charles Bruce, senior physics students at Union College. Pulses of infrared light have been found while the telescope is directed toward the dark side of the moon, but the origin of these pulses is not yet certain. The observational equipment is being refined and will be operated next year.

Mr. Peter Wehinger, a physics major at Union College, is building a photoelectric photometer in preparation for observations at Dudley Observatory next year.

CURTIS L. HEMENWAY, *Director*

Dyer Observatory, Vanderbilt University, Nashville, Tennessee

Personnel: Dr. Robert H. Hardie was promoted to the rank of Associate Professor of Astronomy and Physics. Mrs. Patricia Hudgens, Charles Tolbert, Robert Cameron, Sam Lott, Carl Seyfert, Jr., Dr. Leverett Chapin, William Brown Jr., Harry Gray, and Worth Bowman served as Observatory Assistants.

Instrumentation: Auxilliary apparatus is being constructed to permit using the photoelectric photometer as a multi-beam device. The primary function of this device will be the measurement of $H\beta$ line intensities in the manner of Strömgren. It is also planned for simultaneous UBV photometry and other multicolor work with suitable dichroic beam splitters.

The photometer is being modified to incorporate a light-chopper so that star and sky are alternately admitted to the photocell, a system which preserves the efficiency of the DC techniques and offers certain advantages of AC techniques. Further work in the near-infrared photometry is being postponed until the completion of the chopper device. Electronic units, such as integrators, AC amplifiers, and digitizers, are being constructed for use with the foregoing equipment.

Research Programs: Photoelectric magnitudes, colors and spectra are being obtained of the

nearer OB associations in an attempt to improve distances to the arms in which they lie. Results for the I Lacertae association have been published and those for the II Persei and I Geminorum associations are in manuscript. The photoelectric observations of the magnitudes and colors of the brighter members of the II Scorpii association are complete. Emphasis is now being placed on obtaining photoelectric $H\beta$ intensities of the association members in order to improve significantly the distances to the associations.

Seyfert is investigating the possibility of detecting faint association members through the use of liquid or interference filters in conjunction with the objective prism. Stars earlier than F2 can be selected through the comparison of the H and K lines of ionized calcium and spectral classes derived for the interval between Ao and Fo. By use of filters which pass only the region between 3900 and 4000 Å, it is possible to make objective prism exposures of at least three hours, or 10 times longer than without the filter. Preliminary results indicate that with this method A stars can be classified at least one magnitude fainter than had previously been possible.

Lott and Hardie have completed three-color observations of the ultra-short period variable DY Herculis and are at present analyzing this material. Another ultra-short period variable, CY Aquarii, is under current study by Tolbert and Hardie. The calibrating of a system of faint UBV standard stars is being undertaken by Cameron under the direction of Crawford and Hardie.

Tolbert, Crawford, and Hardie are currently programming the routine photometric reductions for the IBM 650 computer recently installed at Vanderbilt University.

Photographs of Mars were obtained at the 1958 opposition with the television seeing compensator described in *Dyer Reprint* No. 5. The compensator technique has proved quite effective in stablizing images against lateral movement. The photographs indicate that under the best seeing conditions an improvement in detail can be realized.

It has long been thought that the orthicon tube offered promise in the field of faint star and spectral photography. The development of the General Electric Z-5294 orthicon with its superior storage characteristics has caused us to direct our attention to the development of a slow scan system which it is hoped will give a considerable gain over the use of photographic plates directly at the focus of the telescope. Work is progressing on the construction of this equipment under a National Science Foundation grant to DeWitt.

These researches are being supported by the National Science Foundation, The Research Corporation, the National Science Research Committee of Vanderbilt University, and WSM of the National Life and Accident Company.

Miscellaneous Activities: Approximately 1500 persons visited the observatory during the last year, mainly as members and guests of the Barnard Astronomical Society. Among the visitors to the observatory were Dr. Bengt Strömgren of the Institute for Advanced Study, Dr. Armin Deutsch of the Mt. Wilson and Palomar Observatories, Dr. Otto Franz of the Naval Observatory, Dr. Philip Keenan of the Perkins Observatory, Dr. Robert Kraft of Yerkes Observatory, Dr. Arthur Beer and Dr. Raymond Littleton of Cambridge, England, Dr. Karl Henize of the Smithsonian Astrophysical Observatory, Dr. R. H. Stoy of the Royal Observatory, Cape of Good Hope, South Africa, and Dr. J. J. Raimond of the Hague, Netherlands.

Crawford was guest investigator at McDonald, Lick, and Kitt Peak Observatories during the summer. Seyfert continued as member of the Board of Directors of the Association of Universities for Research in Astronomy, and of Associated Universities, Inc., and as a member of the Astronomy Advisory Panel to the National Science Foundation. Crawford lectured at the National Science Foundation institute for high school science teachers at the University of Wyoming and Seyfert at the corresponding institutes at Murray State College, Virginia State College, and Peabody College for Teachers. Crawford and Seyfert presented invited papers on OB associations at the Southeastern Section of the American Physical Society at Loyola University on April 11, 1959.

Publications: A. J. Dyer Reprint No. 9. "A Study of the I Lacertae Association" by R. H. Hardie and C. K. Seyfert, *Ap. J.* **129**, 601, 1959.

A. J. Dyer Reprint No. 10. "An Improved Method for Measuring Extinction" by R. H. Hardie, *Ap. J.* **130**, 663, 1959.

CARL K. SEYFERT, *Director*

Flower and Cook Observatory, University of Pennsylvania, Philadelphia, Pa.

Personnel. Dr. L. Binnendijk was promoted to Professor effective July 1, 1959. Dr. T. K. Menon arrived in November after a visit to the Mount Stromlo Observatory and the CSIRO Radio Astronomy facilities in Sydney. Mr. R. H. Koch was appointed Pawling Fellow for 1958–59. Mr. Koch and Mr. L. W. Fredrick received the Ph.D. degree in June 1959. Mr. K. C. Chou received the M.S. degree. Dr. Koch has accepted appointment at the Amherst Observatory; Dr. Fredrick is at the Lowell Observatory as a member of the DTM; he is engaged in astronomical applications of image converter tubes. Mr. G. E. McClusky is spending the summer of 1959 as an undergraduate assistant at the National Radio Astronomy Observatory.

Instrumentation. The only changes aside from routine maintenance were the replacement of the gears and bearings in the right ascension controls for the siderostat of the 15-inch horizontal telescope. The gear system was modified to increase the slow motion speed by a factor of four.

Scientific Programs. Dr. C. P. Olivier continued his work as President of the American Meteor Society. Two papers are nearing completion; one of them will be an extensive catalogue of daily and hourly meteor rates for over 57 years.

Dr. Binnendijk continued making systematic photoelectric observations of W UMa type binaries using the 28-inch reflector. Light curves in two wave-length bands of U Peg were completed. These show a definite change from those found by LaFara. Orbital elements were derived. The light curve of V839 Oph was observed. During the year, photoelectric light curves of V566 Oph and AB And were published (*A. J.* **64**, 65–73, 1959; *Flower and Cook Observatory Reprint* No. 113).

Dr. Blitzstein continued the measurement of characteristics of multiplier photocells and the development of test apparatus for this purpose. A systematic analysis of possible sources of error in the Pierce photometer was initiated in order to determine quantitatively its practical limitations. As a consultant for the Radio Corporation of America at Moorestown he developed satellite orbital determination methods for use with radar, error analyses of these methods, and orbital improvement techniques.

Dr. Protheroe continued his studies of correlation of stellar shadow bands in upper air winds and turbulence. The optical Fourier analyzer was modified to measure six different spatial components in the shadow band pattern; namely, 21.1, 14.9, 10.8, 10.5, 7.5, and 5.4 cm. A further modification to the instrumentation was the addition of a tape recorder, which permits the output of the photocell to be studied in detail using a homogeneous signal sample at all frequencies. The data taken on 18 different nights from January through March, 1959 are now being reduced. The preliminary results indicate that the shadow band patterns have a structure with a velocity correlated with the upper air wind velocities but that a considerable portion of the scintillation noise detected with a finite aperture is due to time changes in the pattern and not simply to the influence of pattern motion upon the aperture sampling. On a number of nights double patterns with different velocities have been detected. In most cases it appears that the element sizes reach a peak in strength somewhere near 15 cm and that the spatial power spectrum decreases sharply toward longer wave-length as well as the shorter ones. The work is now in its final stages, observations have ceased, and a final report is in preparation. This work has been supported by the Geophysics Directorate Air Force Cambridge Research Center.

Dr. Menon has been using the 85-foot radio telescope at the National Radio Astronomy Observatory to study the 4 cm continuous radiation from *H*II regions such as the Orion nebula and NGC 2244, in order to determine the true electron density distribution within these nebulae. The reductions of the observations are complete and he is now working on the interpretation. He also has been studying the variation in the neutral hydrogen content of the vicinity of the Cygnus loop and NGC 2264. The observations are still in progress.

Mr. H. Heskett, of the Moore School of Electrical Engineering, has completed the construction of a radiometer to be used in conjunction with an 8-foot antenna, for solar polarization studies.

Dr. F. B. Wood continued work on the observational material obtained at the Mount Stromlo Observatory in 1957–58. A paper describing the light and color variations of the intrinsic variable SX Phe is in press. New light elements have been

determined for TZ CrA, V Tuc, and RS Lep. A solution has been obtained for TZ CrA, and a discussion of it prepared. The system is an extraordinarily close one, the radius of the larger star being 0.39 at the distance between the centers and that of the smaller being 0.27. There is evidence to indicate that the smaller, cooler component is overluminous for its mass. Dr. Wood also continued the Card Catalogue of Eclipsing Variables.

Dr. Koch completed orbital solutions and discussions of the eclipsing variables R CMa, AO Cas, AS Eri, and XY Leo. The studies were based on a large number of two- and three-color photoelectric observations which he had obtained at the Steward Observatory of the University of Arizona in 1955–57. In each case, small intrinsic variations were detected.

Dr. Fredrick completed a study of VV Cep based on four color photoelectric observations made with the 15-inch telescope and the Pierce pulse-counting photometer and astrometric observations based on plates taken over many years at the Sproul Observatory. The astrometric and photometric results agree in showing that the M-component does not necessarily have the extremely large radius found in previous discussions; the discrepancy between the luminosity indicated by these results and that indicated by the spectrum can be explained by the large magnetic field associated with the star. Observations were also made on ϵ and ζ Aurigae.

Mr. Chou made photoelectric observations with the 15-inch telescope and the Pierce photometer to determine times of minima of the eclipsing systems. New light elements were derived for TV Cas, XX Cas, BX And, WW Aur, and W UMa.

Mrs. B. B. Bookmyer used the same equipment to observe minima of AK Her and W UMa and to start observations to cover the entire light curve of RS CVn.

Mr. E. G. Reuning continued the development and construction of the infrared photometer, with the advice of Dr. Blitzstein. The photometer was used by Mr. Reuning on the 28-inch reflector to select the most promising objects for an observing list and to determine the limiting magnitude in the 1–2 micron region as a function of spectral class. It was found that at 1.65 microns only objects of class KO and later give signal-to-noise ratios large enough for photometric purposes. The mechanical and optical parts of the photometer are now complete and the final modification of the electronic circuit is nearly complete. This work was supported in part by a grant from the National Science foundation.

In March, Dr. G. R. Miczaika kindly offered, on a long term loan, the photometer constructed by himself and Dr. D. J. Lovell. Current plans call for the eventual operation of two photometers in the 1–4 micron region; one will operate here on programs suitable for the 28-inch, the other will be available as opportunity arises for short-term programs on larger telescopes elsewhere. In June, 1959 Mr. J. F. Wanner joined the infrared project as research assistant; Mr. Chou and Mr. K. Y. Chen worked as part-time research assistants. This part of the work was aided by a contract with the Air Force Cambridge Research Center, Air Research and Development Command.

Miscellaneous. The graduate program was revised and expanded. Dr. Binnendijk's book "Properties of Double Stars" is through the page proof and should appear soon.

FRANK BRADSHAW WOOD, *Director*

Harvard College Observatory, Cambridge, Mass.

Personnel. Professors Donald H. Menzel, Cecilia Payne-Gaposchkin, Thomas Gold, Theodore E. Sterne, and Fred L. Whipple, and Dr. Gerhard R. Miczaika served as the Harvard College Observatory Council during the year.

Dr. Walter Baade was Visiting Lecturer on Astronomy in the fall term of 1958–59, and gave the course on Galactic Structure.

At the close of the academic year, resignations became effective for Gold, who will go to Cornell University, and Sterne, who will go to Johns Hopkins University. On April 30, 1959, Dr. Henry J. Smith resigned as astronomer-in-charge of the Harvard program at Sacramento Peak Observatory, to accept an appointment on the Sacramento Peak staff. Miss Margaret Olmsted retired in December 1958.

Dr. Max Krook received an appointment as Professor of Applied Mathematics and Astrophysics starting in July 1959. Dr. A. Edward Lilley will join the Harvard staff in July 1959.

Visitors to the Observatory included Drs. Horace W. Babcock, Mount Wilson and Palomar Observatories; Arthur Beer, University of Cam-

bridge; Alla Massevich, USSR Academy of Sciences; Donald E. Osterbrock, Washburn Observatory; Gart Westerhout, Leiden Observatory.

Sixteen staff members attended the Tenth Congress of the International Astronomical Union in Moscow in August 1958.

Equipment. The 116-year-old 15-inch refractor in Cambridge has been adapted for use on a solar observing program. A Halle filter will allow $H\alpha$ photography. New controls are being installed on the telescope to improve the guiding system.

At the George R. Agassiz Station, the optics of the 61-inch reflector were realuminized in the summer of 1958. Tests of the UV Newtonian spectrograph, now in use, show that the rigidity of the instrument has improved. A grating spectrograph for the Cassegrain focus was ordered from Boller and Chivens in South Pasadena, California, for delivery late in 1960.

The 24-inch reflector was used for photoelectric work by Dr. Allan F. Cook and Andrew T. Young. A commercial amplifier for the photoelectric photometer was purchased.

The new 21-cm receiving system on the 60-foot radio telescope was brought to a reliable working condition. The preamplifier is now mounted in a box in the focus of the antenna. The stability and sensitivity have been greatly improved.

A 21-cm Maser system was constructed by Dr. John V. Jelley and Brian F. C. Cooper in the Gordon McKay Laboratory with the help of Dr. N. Bloembergen and other members of Harvard's Applied Physics Department. The system works satisfactorily, and is small and light enough to be attached at the focus of the 60-foot dish. Installation is scheduled for the summer of 1959. A platform has been built for work with the Maser on the 60-foot.

A receiving system for the hydrogen-line Zeeman effect is under construction. The initial version will include a two-mixer system attached to a horn feed giving two perpendicular linear polarization outputs. Switching systems and detectors will allow an accurate comparison of the two components of circular polarization. However, this system will probably not yield results until it can be supplemented with low-noise receivers.

The sweep-frequency equipment at the Radio Astronomy Station in Fort Davis, Texas, now includes a further two octaves of the electromagnetic spectrum. The two new receivers, 25–50 and 50–100 Mc/s, began operating in January 1959. They are connected to two fixed broad-band dipoles, which are mounted cross-polarized above a reflecting screen. A new display unit incorporates a further three cathode-ray tubes in addition to the original three-channel system. It is photographed by a specially designed 70-mm continuous-motion camera. The Station has acquired a fluxgate magnetometer, to record the transient variations in the terrestrial magnetic field. Units were built to calibrate the solar spectral equipment automatically in frequency and intensity.

At Sacramento Peak, a polarizing beam splitter added to the 6-inch coronagraph produces simultaneous observations of prominences in $H\alpha$ and at a slightly displaced wavelength, for studies of prominence motions in three dimensions. The remounting of the large-scale disk cinematograph and the Universal spectrograph on the 16-inch coronagraph provides greater speed and facility of operation. In June 1959 the Jarrell-Ash Company began installation of the new triple-monochromator spectroheliograph.

Research. Dr. Payne-Gaposchkin continued her study of the phenomena of novae, and of the interrelationships among both types of Cepheids.

Dr. Sergei Gaposchkin has analyzed about 185 of the 573 spectrographic plates of variable stars which he made during his recent stay at the Mount Stromlo Observatory. He has studied the changing velocities of the different layers, particularly for the Cepheids κ Pavonis, β Doradus, and L_2 Carinae, and has determined that the Wolf-Rayet star, γ Velorum, is an eclipsing variable. From red and blue plates, he has been studying the magnitudes, colors, and distribution of some 3000 stars in the globular clusters ω Centauri and 47 Tucanae.

Gold has carried out theoretical investigations of the Van Allen radiation zone, and of the general question of particle fluxes and magnetic fields in the solar system. He also studied the dynamics of the earth's outer atmosphere, and elucidated the nature of the magnetic restraints; this relates to the investigation of ionospheric motions and other high-altitude phenomena.

Problems of magnetohydrodynamics and magnetohydrostatics and their applications to the solar corona and the vicinity of the earth were treated by Dr. James D. Murray.

In collaboration with M. Harwitt, a graduate

student at M.I.T., Gold carried out experiments relating to erosion of the lunar surface, and demonstrated the extreme importance of electrostatic forces on dust particles in the presence of bombarding electrons. Migration of surface dust on the moon may be attributed to such an effect.

At Agassiz Station, 21-cm observations were carried out chiefly to test the new system. Some observations of M33 were made, but require repetition when the sun is in a different position. Broad-band noise from Jupiter has been under observation, after the information from Green Bank that anomalous centimeter radiation comes from Jupiter.

Krook has developed a number of mathematical procedures for solving the structure equations for non-gray stellar atmospheres. Extensive calculations with one of these methods have been made by John Gaustad and Peter Stone; the method has been shown to converge rapidly. Krook continued his theoretical investigations in the kinetic theory of neutral and ionized gases. He has developed and applied new types of approximation procedures to solve the kinetic equations for the structure of shock fronts, and for other nonlinear problems.

Dr. David Layzer continued a theoretical investigation of atomic spectra. The first full-scale report on this work, "A Screening Theory of Atomic Spectra," will appear in the Annals of Physics. Further applications of the theory include calculations of absolute transition probabilities in neutral and moderately ionized atoms; absolute term values for atoms in the second short period and first long period (*Na* through *Xe*) and their isoelectronic sequences; screening constants for X-ray spectra; fine structure of spectra of atoms in the first and second short periods. Associated with Layzer in the program were Daniel Thompson, Dr. Carlos M. Varsavsky, Dr. Ali Naqvi, and Fred A. Franklin. The work is partially supported by the National Science Foundation.

Layzer has also developed a new mathematical formulation of the theory of ionospheric cross-modulation. In some phases of this work he has been associated with Menzel.

Sterne continued his researches in celestial mechanics, with emphasis on satellite motions.

Dr. Gerard de Vaucouleurs, in collaboration with A. de Vaucouleurs, pursued the reduction of photographic, spectrographic, and photoelectric observations of bright galaxies secured in previous years. Observations made with the Mount Stromlo 74-inch reflector served as material for a classification and radial velocity survey of 50 southern galaxies, and a new determination of the rotation curve and mass of the Large Magellanic Cloud from optical radial velocities of emission nebulosities. Observations made with the Lowell 21-inch reflector formed the basis for a photoelectric survey of magnitudes and colors of 124 northern galaxies, and a detailed determination of the color and luminosity distributions in M33.

A grant from the National Science Foundation allowed initiation in March 1959, of a two-year program of photoelectric photometry of bright galaxies, using mainly Mount Stromlo plates. The objectives include the study of luminosity distribution laws in relation to galaxy types and the determination of integrated photographic magnitudes of southern galaxies, which are still very poorly known.

Whipple continued as Professor of Astronomy at Harvard and as Director of the Smithsonian Astrophysical Observatory. Besides his direction of the Harvard meteor projects reported below, he completed a paper "On the Distribution of Semi-major Axes among Comet Orbits" which applies stochastic methods to determine the distribution of potential lifetimes among comets newly introduced to the inner regions of the solar system. For the long-period comets the potential lifetimes follow a distribution law according to the inverse 1.5–1.7 power of the lifetime. Random perturbations by Jupiter can account for the long-period comets but close approaches to this planet are probably required to account for the occurrence and distribution of the short-period comets.

Whipple and Robert J. Davis have completed the design of a telescope for use in space. The instrument will include an optical system, a detecting device, circuits to amplify and modify the output signal of the detecting device, and the auxiliary circuits necessary to protect the instrument from the effects of direct sunlight. Fitted into a socket in a "stable platform" within a satellite, the telescope will obtain important astrophysical data. The chief goals at present include an ultraviolet survey of the sky in three wavelength regions, and spectroscopic studies of particular celestial objects. Completion of the project will require about three years.

Planetary Atmospheres. Under contract with the Air Force Cambridge Research Center, Menzel, de Vaucouleurs, and Hector C. Ingrao have investigated technical problems of high-resolution photography and spectroscopy of the planets by means of balloon-borne telescopic systems. Preliminary designs for 24-inch telescope systems (manned and unmanned) submitted by several companies are under consideration.

A program has begun for photographic mapping of surface and atmospheric features of Mars in 1954 and 1956. Dr. W. S. Finsen and Dr. R. B. Leighton kindly made available their extensive series of photographs taken, respectively, at the Union Observatory, Johannesburg, South Africa, in 1954–56, and at the Mount Wilson Observatory in 1956. Composite prints have been prepared. Automatic computing methods will be used in the reduction. As a supplement, several thousand brightness estimates of the various regions of Mars made at the oppositions of 1941 and 1958 are being prepared for reduction.

De Vaucouleurs secured visual and photoelectric observations of Mars in October and November 1958 at the Lowell Observatory. The Russell-Bond albedo of the planet was measured at five wavelengths from λ3300 to λ6900. In the near ultraviolet, $3000 < \lambda < 4000$, Mars seems to be "gray" and very dark (albedo = 0.046), an appearance difficult to reconcile with some current ideas on the nature of the blue haze. An outstanding yellow cloud, observed October 13–22, provided significant new information on atmospheric circulation and diffusion rate.

The occultation of Regulus by Venus on July 7, 1959, was successfully observed at six of the eight stations manned and equipped for visual, photographic, and photoelectric observations under Menzel's direction. With the co-operation of the various directors, teams worked at observatories in Madrid, Le Houga in southern France, four stations in Italy, Beirut, and Bloemfontein. Provisional reductions of data from one station have been made (*Harvard Announcement Cards* 1442, 1443, and 1444). Principal sponsorship of the expedition was through contract with the Air Force Cambridge Research Center; the Boeing Airplane Company also provided support.

Meteor Research. The meteor project, under the direction of Whipple and Dr. Richard E. McCrosky, received continuing support from the Air Force. Routine operation of the meteor stations at Sunspot and at Organ Pass, New Mexico, was discontinued for an indefinite time on January 15, 1959. From January 1952 to January 1959, some 6600 double-station meteors were photographed, a sufficient number to give a statistical survey of visual meteors. Future operation will depend on the development of new observing techniques.

McCrosky and Mrs. Annette Posen are continuing an analysis of the orbits of the meteors photographed from 1952 to 1955.

Cook furthered his analysis of meteor trains for the determination of upper atmospheric winds and the structure and mass of meteors. The work of Cook and Franklin on the structure of Saturn's ring is progressing, and Franklin is now at the Boyden Observatory to obtain photoelectric and photographic observations to augment the existing data.

McCrosky analyzed the available data from an Air Force attempt to produce artificial meteors by the high-velocity ejection of material from rockets. The technique may prove useful in calibrating the mass scale of natural meteors. McCrosky and Cook are co-operating with several high-speed ballistic laboratories in the design of future experiments.

Cook continued work on the quantitative analysis of the spectra of meteors, in collaboration with Dr. Peter M. Millman of the National Research Council of Canada and Dr. Ian Halliday of the Dominion Observatory in Ottawa.

Dr. Frances W. Wright analyzed the radiant motion and scatter for the photographic Lyrid meteors. She continued supervision of the examination of all meteor film taken through January 15, 1959, with the Baker super-Schmidt cameras.

The research program supported by the Lincoln Laboratory of M.I.T. has continued. Dr. Gerald S. Hawkins, Francis M. Stienon, and Richard B. Southworth found that vestiges of the great Andromedid meteor swarm are now scattered over a wide area in the plane of the original comet orbit. Hawkins, Mrs. Barbara J. Cormack, and Southworth compiled a table of orbital elements of 360 meteors photographed by the super-Schmidts. Hawkins has shown that the dividing line distinguishing cometary meteors from asteroidal particles occurs at a visual magnitude of -3. Brighter fireballs derive largely from solid fragments of broken asteroids;

meteors fainter than −3 are produced largely by the low-density "dust balls" that come from comets. In the field of meteor physics, studies have been made of long-enduring meteor trains and turbulence in the upper atmosphere. Cook and Hawkins showed that the radar head echo from a meteor is probably caused by photo-ionization of oxygen molecules. William E. Howard, III, and Hawkins made a photometric study of the decay of light from enduring meteor trains. Donald M. Lazarus completed a theoretical investigation of the ionization cross-section for the collision of sodium atoms on an atmosphere of oxygen atoms; this work relates directly to the ionization process in meteor trails.

The radio meteor project, supported by a contract from the National Bureau of Standards, continues under the direction of Whipple, with Hawkins as astronomer-in-charge and E. Stuart Fergusson as project engineer. Construction and testing of electronic equipment began in 1958. Meteors will be tracked by radar reflections to provide data on the velocity, radiant, and orbit of individual meteors. Dr. Littleton Meeks joined the project to assist in the coding of the 704 IBM machine for the reduction of the data. A large "trough" antenna was constructed by Radiation Engineering Laboratory at the main site in Havana, Illinois, and the transmitter has already been put into operation by the National Bureau of Standards. Microwave radio relay links were installed by Raytheon and the construction work at the site is almost completed. Gunther Schwartz has transferred from the super-Schmidt station at Sacramento Peak to the observing site of the radio meteor project.

Solar Studies. Menzel continued to direct various aspects of solar research under contract with the Air Force Cambridge Research Center. He further developed his studies of the form and structure of solar prominences, especially as they relate to the solar corona. Recent 5303 coronal photographs from Sacramento Peak Observatory are of high quality and show structural details not previously detected. Rapid changes occur in the corona, from hour to hour, often resembling surges. Concentric loops often form; these are related to the well-known "petals" of the corona, and are clearly also associated with the loops in $H\alpha$.

Motion picture records indicate that, in many instances, prominences at low temperatures and high densities condense from the corona at high temperatures and low densities. Dr. Martha Hazen and Lowell Doherty have collaborated with Menzel in investigating the relative importance of various processes responsible for the cooling of the corona. The ultraviolet radiation field in prominences determines the relative numbers of neutral and ionized hydrogen and helium atoms, which produce the visible light of the prominence. They found also that radiation from the million-degree corona contributes little directly toward establishing the hydrogen and helium abundances, but the heavier elements on which the corona can act more effectively in turn strongly affect the light ions.

Dr. Barbara Bell used Mount Wilson data on the magnetic field strengths and numbers of sunspots for the years 1917–1958 to study the structure of the sunspot zone as a function of heliographic latitude. She found some, but inconclusive, evidence in favor of the hypothesis that several zones of activity develop in each solar hemisphere, and that the zones remain stationary in latitude and are just sufficiently out of phase to simulate the latitude shift over the solar cycle described by Spoerer's law.

John G. Wolbach continued his study of the F_2 layer of the ionosphere. From characteristics of about 75 stations he found evidence for six categories of f_0F_2 variation with time. The characteristics of low-latitude stations in the northern hemisphere are found in certain southern hemisphere stations even at high latitudes, particularly at sunspot minimum. At sunspot maximum these stations tend more to show the expected variation with southern season.

Dr. Alan Maxwell remained in charge of the Radio Astronomy Station at Fort Davis, Texas. A statistical analysis of the solar radio emissions at four frequencies, 125, 200, 425, and 550 Mc/s, was completed for the Rome Air Development Center. The analysis included a detailed examination of the frequency-time profiles of the solar bursts interpreted in terms of their spectral characteristics.

An extended program on the correlation of radio bursts with the occurrence of optical disk phenomena has been completed. The analysis covered a two-year period at sunspot maximum and compared some 10,000 radio bursts with 2000 solar flares. Further theoretical work included a comparison of the slow-drift radio bursts with the occurrence of terrestrial magnetic storms and aurorae, and a study of the correla-

tion between solar bursts and cosmic rays. Most of the latter work was carried out with the IBM 650 computer at the National Bureau of Standards in Boulder.

The solar project at Sacramento Peak contributed importantly to the world coverage of solar activity during the IGY and its extension. In addition to its patrol function, the project supplies descriptions and copies of routine and special observations of outstanding events to many astronomers.

The 4-inch patrol coronal spectrograph has been used, under the direction of Dr. F. Q. Orrall of the Sacramento Peak Observatory, for the study of highly energetic, transient phenomena in the chromosphere and corona. Spectroscopic data in the near ultraviolet were obtained from loop prominences, surges and eruptive prominences, and limb flares.

The 6-inch coronagraph produced unique cinematographic observations of the *Fe*XIV emission line corona; it is now used less frequently for $H\alpha$ prominences.

The 0.5A flare-patrol camera made high-rate cinematographic studies of the $H\alpha$ activity of the chromosphere, as well as routine surveys. Results from the Fort Davis dynamic spectrum analyzer have shown that the normal 5-minute or 2.5-minute rate of the flare patrols fails to reveal a major part of the time spectrum of solar activity. The few high-speed sequences obtained to date do not show complete correlation between activity in the radio spectrum and $H\alpha$, but a new category of short-lived events, "high speed brights," has been detected.

Dr. Elske v. P. Smith continued observation of the height gradient of chromospheric hydrogen line profiles. In collaboration with J. T. Jefferies and J. Zirker, she has secured observations of sensitive metallic lines in the spectrum of chromospheric plages.

Dr. Henry J. Smith completed a study of the heliographic distribution of solar flares and, with E. Smith, continued to collect Universal spectrograms of bright prominences and limb flares, and high-resolution $H\alpha$ cinematograms of chromospheric activity. William Booton worked with H. Smith to study the relations between flare growth curve characteristics and position on the disk, intensity, importance, and area.

H. and E. Smith have designed and tested a number of automatic digital computer programs for the reduction of spectrophotometric data, using the Univac installation at the Holloman Air Force Base. This work involves techniques to interpret the specialized format of microdensitometer data and to smooth photographic grain noise, and tests of all well-known methods for correcting spectroscopic observations for instrumental profile.

Department of Astronomy. Professor Payne-Gaposchkin continued as Chairman. Sixteen graduate students were in residence during the academic year. Varsavsky received a Ph.D. degree in March 1959, and Eugene E. Epstein, an A.M. degree in June.

Paul W. Hodge, a graduate student, spent six months at the Boyden Observatory in Bloemfontein, South Africa, obtaining plates for photometry of stars in the Large Magellanic Cloud.

Miscellaneous. Over 2000 visitors attended two series of Open Nights, held under the direction of Miss Wright. Doherty, Hodge, Menzel, de Vaucouleurs, and Whitney gave lectures.

Menzel continues as Chairman of the Boyden Administrative Council. The annual meeting was held in August 1958 at Hamburg, Germany.

A bibliography of Observatory reports and publications for the year July 1958 to June 1959 will be available in late fall on request from the Librarian, Harvard College Observatory.

DONALD H. MENZEL, *Director*

High Altitude Observatory of the University of Colorado, Boulder and Climax, Colorado

Personnel. During the last year Dr. Bernhard Haurwitz joined the Observatory staff and was appointed Professor of Astro-Geophysics in the University. He came to HAO from New York University, where he headed the Department of Meteorology and Oceanography. Other new research staff members are as follows: (a) at Boulder, Mrs. Sandra Carlen, Mr. Paul R. Julian, Mr. Eugene P. Laybourn, Mrs. Betty Tanner; (*b*) at Climax, Mr. Robert B. James, Mr. Roland Manning. Dr. André Boischot held a one year appointment which ended in July. Dr. Sydney Chapman continues to share time between the HAO and the Geophysical Institute of the University of Alaska. The following scientific staff members terminated their appointments: Mr. Kenneth Durbin, Mr. Randy Sherman, Mrs. Mary F. Zirin, Mrs. Barbara Dolder.

Mr. Einar Tandberg-Hanssen returned to Norway in June 1959 for a year's leave of absence.

Research associates for the year included Captain Mary P. Converse, Drs. John T. Jefferies, Jean Claude Pecker, Herbert Riehl, Joseph H. Rush, Richard N. Thomas, Gérard Wlérick and Donald H. Menzel.

Visitors who spent extended stays at HAO included Dr. John Firor, of the Department of Terrestrial Magnetism, Carnegie Institution of Washington; Drs. Julius London and Max Woodbury, New York University; Dr. Malcolm Correll, DePauw University; Dr. Sherman C. Lowell, Adelphi College; Dr. E. K. Smith, National Bureau of Standards; Dr. Marshall Cohen, Cornell University; Drs. Joseph Cain and M. Sugiura of the Geophysical Institute, University of Alaska.

Visitors to the World Data Center for Solar Activity at HAO included Dr. Marcel Nicolet of Belgium and Dr. M. Hasegawa of Japan. The Observatory's annual research review was conducted by Dr. Jesse L. Greenstein, of the California Institute of Technology.

Several members attended the CSAGI of the IAU meetings in Moscow in July and August 1958.

Scientific Equipment and Facilities. During the year the HAO commenced work on the design and construction of a large aperture coronagraph and spectrograph for use at Climax. The new instrument is supported by the National Science Foundation and by private contributions.

Plans were also completed for the construction of a permanent Boulder research center for the HAO, to replace its present temporary and scattered buildings. Funds for this enterprise were contributed by the University of Colorado and by a number of private donors, including the Max C. Fleischmann Foundation of Nevada.

The long-wave radio interferometer of HAO, designed for solar and stellar radio research at 20 and 40 Mc/s has been modified to include rapid-sweep spectrum scans over the range 15 to 33 Mc/s, and will shortly be extended to 50 Mc/s. Fast drift bursts and other interesting solar phenomena are being observed to the full wavelength limits of the equipment.

SCIENTIFIC PROGRAMS

Active Solar Region Analysis. Compilation and distribution of current reports of the state of solar activity continue to occupy a part of HAO's activity. More and more geophysicists are interested in ground, rocket, balloon, and satellite researches that can be assisted by prompt notification of the level and type of solar activity in progress. In this and other research activities the HAO cooperates closely with the Central Radio Propagation Laboratory of the National Bureau of Standards and the Sacramento Peak Observatory.

World Data Center A for Solar Activity, located at the HAO, continues to function as a western world source for IGY solar information. Many of the more important records are being prepared for permanent publication in the *IGY Annals.* Meanwhile, the IGC-59, a continuation of the IGY, has provided new data on slightly reduced scale, that are received, catalogued and distributed from the Data Center. International cooperation in supply of data continues at a level very close to that of the IGY.

Prominence and Flare Physics. Tandberg-Hanssen, Curtis, and Watson observed emission of the *He*I line at 10,830 Å against the solar disk during the great solar flare of 26 August 1958. Their interpretations of the profile of the line do not fit the expected intensity ratios of the components making up the line, making further efforts to observe the line desirable.

Several other line profile studies of prominence and flare phenomena also occupy attention at the HAO. Zirin and Tandberg-Hanssen, for example, have carried out detailed line profile studies of the 19 December 1956 active looped prominence region and other regions. These studies indicate that the line broadening is complex, probably implying that individual prominences contain regimes of very different temperature and pressure over small distance ranges, though several systematic tendencies were discovered.

Coronal Physics. The corona of the sun, partly because of the transparency of its gases, affords a promising field for definitive studies of physical conditions of active regions. Studies of the variations of line profiles with height in various active and quiet regions have been made by Billings, Cooper and others of the staff. Temperatures of several million degrees Absolute are found near the tops of loops of active coronal looped prominences, with the yellow coronal line at 5694 Å pronounced in the hottest regions, as one might expect. Some regions show fluctuations of line breadth suggestive of hydromag-

netic waves in the solar atmosphere. Further pursuit of this mode of analysis may yield information on solar atmospheric magnetic field distributions, information of crucial importance in solar physics today.

Newkirk has nearly completed the analysis of electron corona observations to derive a model of the electron density distribution of an active region, and has computed theoretical optical paths for various radio noise rays through the model atmosphere. He also made a search, with negative results for regions of the electron corona with measurable departures from radial optical polarization.

Sanford Schwartz completed his Ph.D. thesis research under the guidance of Harold Zirin. This work comprised a new calculation of the ionization cross-section of *Fe*XIV by electron collision. For the analysis a hydrogen-like model of the atom was used, and all continuum wave functions were assumed to approach Coulomb functions at large distances from the atom. The cross sections resulting from this are about one-tenth the values in current use. The new values lead to higher values of the electron kinetic temperature, of about 2×10^6, in good agreement with ion kinetic temperatures derived from Doppler line broadening—by Billings and others.

Chromospheric Research. Previous observations of chromospheric spicules in $H\alpha$, $H\beta$, and D3 of helium have been extended to the K-line of $Ca+$ and to the *He* line at 10,830 Å. The $Ca+$ lines behave somewhat differently from the neutral atom lines, but the cause of the behavior is not yet determined.

Extensive preparations for the Canary Islands eclipse of October 1959 have now been made jointly with the Sacramento Peak Observatory. The 1958 eclipse in the South Pacific was totally rained out, so far as the joint HAO-Sacramento Peak optical expedition was concerned. At the Canary Islands, chromospheric flash spectra will be taken at substantially higher resolution than before, and with a rate of several spectra per second.

A monograph about the physical conditions of the chromosphere, by Athay and his associate Dr. Richard N. Thomas of the National Bureau of Standards is expected to be finished sometime in 1959. Several research programs on the interpretation of chromospheric phenomena continue.

Solar Radio Noise Research. Warwick, Lee, Boischot and associates have gathered a substantial amount of interferometer and total power solar radio noise data during the year. Swept-frequency radio spectra in the range 15 to 33 Mc/s reveal fast-drift radio bursts with delays of a few seconds in onset over this frequency range, and with appreciably longer pulse duration. Several outstanding solar phenomena, like the powerful radio noise storm after the 22 August 1958 solar flare have also occupied special attention.

The instruments are being used to observe stellar source scintillation, radio noise absorptions, and also detected the decay of the spin rate of Sputnik I in 1957, though analysis of the data has just recently been completed.

Ionospheric and Geomagnetic Research. Variations of geomagnetic elements over the closely-spaced U. S. grid of IGY geomagnetic stations are under study by Matsushita. These data are being interpreted in terms of atmospheric current winds in the E region. In particular, extensive studies have been made of the apparent effects over U. S. following the August 1958 high atmosphere hydrogen nuclear bomb experiments.

Studies of the origin of geomagnetic and ionospheric storms are also in progress. Estimates of the mass motions and total kinetic energy of the E-region airglow circulation have been conducted recently in cooperation with Dr. Franklin Roach of the National Bureau of Standards.

Solar Weather Research. Macdonald and Roberts are continuing their efforts to test the apparent association of geomagnetic activity with the development of large scale troughs in the stratospheric circulation. Surprisingly enough, the work of two previous winter seasons received an independent confirmation in the behavior of the 1958–59 season. It seems that trough systems at 500 mb. appearing in the vicinity of the Aleutian Islands two, three or four days after a large aurora or magnetic storm have a materially heightened probability of becoming, at maturity, larger systems than otherwise. The result, however surprising, suggests that speculations about possible physical mechanisms must be attempted.

Newkirk has completed preparations for a series of balloon flights to stratospheric levels to observe, with a small scale coronagraph, the intensity distribution with height and angle from the sun of the terrestrial atmospheric aureole. The analysis of such data can lead to important information on atmospheric dust or ice particles

of terrestrial or cosmic origin, or produced by the influence of solar activity. These, in turn, have great potential value in meteorological research. Ultimately we hope to measure such aureoles from various geographical locations on days related to magnetic storms, meteor showers, unusual jet stream phenomena, and on dates of the apparent rainfall singularities discovered by E. G. Bowen of Australia.

WALTER ORR ROBERTS, *Director*

University of Illinois Observatory, Urbana, Ill.

Personnel. During the year 1958/59 the permanent senior staff consisted of Drs. G. C. McVittie, S. P. Wyatt, I. R. King and of Dr. G. W. Swenson, Jr. who held half-time appointments in Electrical Engineering and Astronomy. There were four graduate students in the Department during the first semester and five in the second.

Research Activities. Dr. McVittie investigated the value of the cosmical constant and of the space-curvature constant in the light of Oort's recent (Solvay Conf. 1958) estimate of the average density of matter in space combined with the negative acceleration parameter deduced from the red-shift data. He found that the cosmical constant is negative and that space is hyperbolic and so of infinite extent. McVittie also showed that if the number of extragalactic radio-sources increases with flux-density according to the "$-3/2$ law," there must have been more of these sources in the past than there are now. These results were given in a lecture at the "Colloque International sur les Theories Relativistes de la Gravitation" held at Royaumont, France, June 21–27, 1959.

Drs. McVittie and Wyatt investigated the flux density from all unresolved galaxies in the universe, using Milne's model of the universe. Radio and optical emissions were considered. Comparison was made of the results with those deducible from a partially filled static Newtonian universe (*Ap. J.* **130**, 1, 1959).

Dr. King continued his studies of the dynamics of star clusters, devoting special attention to the effect of galactic tidal forces. A re-examination of the stability problem has led to the recognition of the fundamental role played by the internal rotation of the cluster. As for the escape of stars from a tidally influenced cluster, he has numerically integrated the orbits of escaping stars in order to determine how much opportunity there is for recapture by further encounters. In a separate investigation he has reconsidered the general relaxation problem and arrived at a new estimate of the basic escape rate of stars from clusters.

Dr. G. W. Swenson's ionosphere project, sponsored by the National Science Foundation, continued. The 108 Mc/s interferometers were completed so that the installation now has 20, 40 and 108 Mc/s north–south and east–west interferometers. An automatic timing system for controlling the recording program has been installed. A Cossor ionosphere sounder has been furnished by the Nation Bureau of Standards.

The chief observational effort has been the daily monitoring of the 20 and 40 mc signals from satellite 1958 Delta II (Sputnik III). With the assistance of Dr. K. C. Yeh of the Electrical Engineering Department, Swenson has analyzed the signals from satellites 1957 Alpha II and 1958 Delta II over a 20 month period to determine the diurnal and seasonal variations of the incidence of scintillation. Marked diurnal effects were noted, the scintillation being much more frequent at night. This night-time scintillation is correlated with the occurrence of ionospheric "spread-F" and apparently originates in inhomogeneities at heights of about 220 km and, in most cases at latitudes greater than 40°N. Daytime scintillation appears to originate in small inhomogeneous regions below 200 km which are more widely distributed in latitude.

Another aspect of this project involved a re-analysis by Wyatt of the period changes of 1958 Beta II (Vanguard). In addition to the correlation with solar activity discovered by Jacchia, Wyatt finds that Jacchia's "diurnal" effect correlates with the local solar time at the perigee of Vanguard. Maximum drag occurs in early afternoon at perigee and is greater by a factor of five or so than the drag in early morning or early evening. It appears that the exosphere expands and contracts daily, with maximum density and temperature at 650 km an hour or two after noon. The period changes also show some dependence on seasonal insolation. Particularly well defined are the decreases in drag which occur when the perigee is at maximum latitude at or near the date of the winter solstice; the effect is considerably more pronounced in the southern hemisphere than in the northern.

Radio-astronomy Project. The engineering work on the construction of the 400 × 600-ft parabolic cylinder continued throughout the year. The consulting engineers, Hanson, Collins and Rice, completed the design of the structure and drew up specifications for the reflecting surface and the four towers which will carry the feed system. The reflecting surface is to be of graded earth covered with asphalt liner for soil erosion control. A wire mesh for high reflectivity is to be placed on the asphalt liner. The towers are 165 ft high and are made of wood. The receiving elements are carried on the underside of a cat-walk running across the top of the towers. It is 425 ft long and there will be about 300 receiving elements. The beamwidth for the operating wavelength of 50 cm will be approximately 20 minutes of arc between half-power points. The telescope is a transit instrument with the 600-ft dimension in the meridian. Beam steering in the meridian plane is to be accomplished by electrical phasing of the receiving elements. Swenson continued to act as project engineer for the construction of this radio-telescope, assisted by two faculty members of the Electrical Engineering Department, Dr. Y. T. Lo and Dr. R. A. Davidson.

Bids for the construction of the reflecting surface and the erection of the towers and crosswalk were called for in June 1959 and the joint bid made by Chism and Miller Inc. (Springfield, Ill.) and the W. B. Clements Co. (Wallington, Ill.) was accepted by the Board of Trustees of the University of Illinois subject to the approval of the Office of Naval Research, which is financing the project. This approval was obtained on August 27 and construction began on September 3, 1959.

The University has purchased approximately 210 acres of land some five miles southeast of the town of Danville, Ill.; this site includes a ravine of the right shape and orientation to accommodate the parabolic reflector. The University is also contributing the cost of a road and of a power-line to the site.

Instruction. The total number of students registered in courses in astronomy during the academic year was 421, which represents a 17 percent increase over the preceding year. Two students entered on the course of study leading to the newly inaugurated Ph.D. degree in Astronomy.

General. Dr. W. W. Morgan (Yerkes Observatory) and Dr. G. Westerhout (Leiden Observatory) each gave a lecture at the Observatory during the year.

Dr. McVittie was appointed a member of the Committee for Observing Programs at Kitt Peak National Observatory. Dr. Swenson was made a member of the NASA Space Sciences Working Group on Satellite Ionosphere Beacons. Dr. Wyatt participated in the Visiting Professors program of the American Astronomical Society and the National Science Foundation making visits in March and April 1959 to four colleges and universities in the Midwest. He also conducted the astronomy phase of a Summer Institute in Science for elementary school science supervisors. This Institute was held at the University of Illinois in the summer of 1959 and was supported by the National Science Foundation.

G. C. McVittie, *Director*

Leuschner Observatory, University of California, Berkeley, California

Professor V. Kourganoff spent the Spring semester in Berkeley conducting a seminar concerning various topics in the theory of radiative transport and the theory of emission lines in various sources. He completed a portion of a new book which deals with these topics.

The Radio Astronomy Laboratory (H. F. Weaver, Director) was established by the Regents in July, 1958. The principal task of this laboratory is to build and to operate an off-campus radio astronomy observatory. During the year of the Laboratory's existence, the following has been accomplished:

1. A large number of possible observatory sites, chosen on the basis of geographical configuration and location, were inspected and tested for radio noise in the frequency range 55 to 900 Mc/s. On the basis of these tests and on the basis of accessibility, a site at Hat Creek, north of Lassen National Park, was chosen. As judged by the comparative noise tests, the Hat Creek site, which is about 300 miles from Berkeley, is one of the most satisfactory ones now in use in the United States.

2. Two paraboloidal antennas, one of 33-feet aperture, the other of 85 feet aperture, are in process of construction or design. The smaller

radio telescope will be built by the Radio Astronomy Laboratory (the dish itself will be built by the Philco Corporation), the larger one will be constructed by a commercial supplier. Both antennas will have solid surfaces, accurate to ±0".125. Pointing and tracking accuracy will be commensurate with this high surface accuracy. The smaller instrument will be in operation by the end of 1959, the larger one in the spring of 1960.

3. Receivers for 8000 Mc/s and 1420 Mc/s will be available within two months.

4. A site master plan and working drawings for the necessary shop and housing facilities for the off-campus radio observatory have been completed. These facilities, which include a dormitory for six observers and houses for a caretaker and an electronics technician, will be available for occupancy by the end of 1959.

The first research program of these instruments will be the study of hydrogen in the vicinity of young clusters and associations. The purpose of the program is the determination of the spatial distribution and kinematic properties of the gas remnants remaining after stellar birth.

A Baker-Nunn Satellite Tracking Camera will be operated at the Hat Creek site. This instrument is one connected with Project Space Track of the Air Force Cambridge Research Center.

Harold Weaver has undertaken to determine a consistent set of galactic parameters. This will necessitate first a discussion of the best numerical values of various kinematic and distance scale parameters that characterize the galaxy. The galactic force law and mass distribution will be derived when the final set of parameters is available. At present, emphasis is on determination of the distance scale and on a discussion of the sources of the discrepancies in the parameters of the local velocity ellipsoid when determined by the dispersion method (proper motions only) or by methods involving radial velocities or space motions.

High-dispersion spectrograms of β Lyrae were obtained by O. Struve with the Coudé part of an international program of photoelectric observations of the light curve of this star. A comparison of the photoelectric observations, by David Wood and Merle Walker at the Lick Observatory, with the spectrographic observations shows an interesting correlation of the intensities of the absorption lines produced by the gaseous shell of the system with the departures of the brightness of the star from a mean light curve. The rotational disturbance of the velocity curve of β Lyrae was found to be strikingly different during two successive primary eclipses. The latter phenomenon shows that the profiles of the absorption lines during the partial phases of the eclipse cannot be fully explained by the geometrical circumstances. It is probable that the differences in the amount of electron scattering in the shell are responsible for the observed changes.

The apsidal motions of the orbits of the stars Y Cygni and HR 8800 were re-investigated with the help of Mount Wilson Observatory spectrograms. The radial velocities of the components of 48 visual double stars were obtained from spectrograms procured during the past nine years. A detailed study of the spectrum of the binary α Virginis by Struve, Sahade, Huang and Zebergs was published in the Astrophysical Journal. The radial velocity measurements of epsilon Aurigae, covering the period from 1928 until 1958, revealed some striking differences from the velocity curve obtained during the preceding twenty-seven year cycle. A study of the spectra of a dozen β CMa variables was undertaken by Charles Stableford and several other graduate students. The equivalent widths of the $H\gamma$ absorption line was plotted for each star as a function of the equivalent width of either the line *Mg*II 4481 or *O*II 4349. The resulting plots not only confirm the period-luminosity relation previously discovered by McNamara and others but they also show that these variables form a band of appreciable width in the HR diagram, such that at any given absolute magnitude, different variables may have appreciably different effective temperatures. A study of the spectrum of YY Geminorum was undertaken in order to investigate the existence of fairly rapid changes in the relative intensities of the hydrogen emission components of the two stars. As a byproduct, a greatly improved velocity curve was obtained.

K. Abhyankar completed his investigation of the spectroscopic orbits and the physical properties of three massive binaries: Plaskett's star, AO Cas and β Sco. Kenneth Widing finished an investigation of the spectrum and the light curve of the peculiar binary 17 Leporis.

John G. Phillips has written a program for

the I.B.M. 701 computer for the reduction and analysis of the rotational structures of molecular bands of the lighter molecules possessing resolvable rotational structures on high dispersion plates. The analysis consists of the search for branches satisfying very loosely-defined criteria. The program has been successfully tested on the (3–0) sequence of the red system of *CN*, and on a very complex region of the *TiO* spectrum in the neighborhood of 6300A. These programs make it possible to reduce enormously the time and labor required to analyze band spectra. Accordingly, in cooperation with Dr. Jenkins of the Physics Department, a program has been established for the routine reduction and analysis of all spectra of molecules of astrophysical interest, as well as molecules of interest to physicists and chemists studying flames, etc. An N.S.F. grant has been awarded the project, providing $123,600 for the first three years. Dr. Sumner Davis of M.I.T. will join the group this summer to provide day-to-day direction of the progress of the work. A semiautomatic plate measuring machine is being built. It will make it possible to punch directly onto I.B.M. cards the position of the line on the plate, and the central density of the line.

Phillips has conducted extensive tests on an optical system incorporating high speed rotating mirror systems for the measurement of lifetimes. The rotor is used both to produce a pulse of excess radiation in a gas, and to analyze the resulting pulse of excess emission from the gas. The gas could be in the form of a molecular beam, or could be produced in a carbon tube resistance furnace. The tests indicated that there is a good likelihood that the method would produce results of physical significance. A more definitive model of the equipment is now being planned, and will be constructed during the next year.

George Wallerstein has been making spectroscopic studies based upon material obtained at the Mount Wilson Observatiory. In concluding an investigation of the population II cepheids W Virginis and M5, No. 42 he finds that the double absorption lines, emission lines of hydrogen and helium, and profiles of the hydrogen lines can be understood in terms of a shock wave moving out through the atmosphere during rising light.

A study of the radial velocity of the helium rich star Sigma Orionis E has been completed by Wallerstein. The star's velocity seems to be constant and very nearly the same as that of sigma Orionis AB. During four hours of observation with the 20″ telescope sigma Orionis E showed no variation in light.

He has made an investigation of the brightest main sequence star in the old galactic cluster M67. The presence of the B8 star and several A stars in the cluster is puzzling in view of the great age that has been assigned the cluster. Wallerstein finds that this B8 star appears to be normal for a B8 star. It shows appreciable rotation, and the absolute magnitude as derived from the equivalent width of $H\gamma$ is the same as that derived by photometric methods. This indicates that the star has the normal surface gravity for a main sequence star and is not a horizontal branch star of 1.2 $M_\odot$.

Using the 20″ telescope at the Leuschner Observatory Wallerstein observed U Geminorum in three colors during an outburst. Two results of interest were obtained. First it was noted that U Gem as well as SS Cygni does not follow the absolute magnitude, rate of decline relation that is followed by the normal novae and repeating novae. Secondly the colors showed such a great ultra-violet excess as to place it in the *B-V*, *U-B* diagram above the line occupied by black bodies. This can be understood in one of three ways: 1—The star may suffer from appreciable circum-stellar reddening (the interstellar reddening in that direction is small). 2—Continuous Balmer emission may be present. 3—The radiation may be partially non-thermal.

H. Spinrad continued photoelectric observations of field RR Lyrae stars. Ten variables were observed in yellow and blue, and five were observed in three colors. The observations show a B-V color dependence on both period and delta s classification, in the sense that the RR Lyrae stars become redder with both increasing period and decreasing delta s value (i.e., increasing metallic line strength). The three-color observations show the strong-lined variables to be depressed below the main sequence in the color-color diagram. Observations of RV UMa and TU UMa have been made in conjunction with a spectroscopic program of Dr. G. Preston of the Mt. Wilson Observatory. Simultaneous photoelectric and spectroscopic observations have been obtained for both variables. BE Monocerotis, a variable classified as an RR

Lyrae 'a' type, has been found to be a Cepheid with a period near 2.6 days.

Morton Roberts held a National Science Foundation Post-doctoral Fellowship at Berkeley. He also was a guest investigator at the Mt. Wilson and Palomar Observatories and at the National Radio Astronomy Observatory.

He started a program of photoelectric observations of galaxies with the aim of studying the color variation across the projected image of the galaxy. Results are available for M32. They indicate that (a) this galaxy is redder towards the center and (b) the color variation differs along the two principal axes of the galaxy.

He has been studying the problem of those stars which sit approximately on the main sequence and above the turn-off point in the color-magnitude diagrams of globular clusters and old galactic clusters. It has been found that these "blue" stars show a non-random distribution in the cluster. In the galactic clusters, this effect is indicated by a projected density distribution of the blue stars which differs from the cluster stars in general. Two possible explanations of these blue stars and their non-random distribution are (1) relatively recent formation and (2) accretion. It should be noted that the conditions for accretion are much more favorable in a cluster than in the general field. Both mechanisms require interstellar matter within the cluster. Observations for neutral hydrogen in the globular clusters M3 and M13 were made with the 85-foot radio telescope at Green Bank. A preliminary value for the upper limit of neutral hydrogen in these clusters is 300 solar masses. Many clusters show prominent regions where there is an apparent absence of stars. M13 is an outstanding example. The construction of a synthetic cluster indicates a very small probability that these regions are caused by statistical fluctuations in the distribution of stars. It must be assumed that they are caused by extinction due to interstellar matter. The frequency of these absorption regions makes it unlikely that they are all foreground clouds. The presence of such intraglobular clouds could account for the "blue" stars in clusters.

John A. Crawford investigated the Fermi acceleration produced by magnetic storms in the region of the outer van Allen belt of terrestrial radiation. It was found that electrons are locally accelerated in closed magnetic loops left behind by the receding storm to such an extent that the observed radiation can be accounted for. Collisions between electrons, which tend to oppose the Fermi acceleration, were taken into account in the complete Fokker-Planck equation. It appears therefore that it is not necessary to assume that solar storm clouds carry the radiation from the sun to the earth, as has been suggested by Gold (*Nature* 183, 355, 1959).

Louis Henyey, Nancy Gould, and Jack Forbes have been preparing a code for the IBM computer to carry out automatic calculations of stellar evolution. The program will be used shortly after the installation of the Berkeley 704 on 1 November, 1959. It is planned as a general utility program which, with minimum modifications, can be used in connection with a large variety of conceivable problems. Approximately one evolutionary time step will be calculated in one to two minutes of machine time. The method of calculation is similar, but in general terms only, to one described in the May, 1959 issue of the Astrophysical Journal. A report on the method is in preparation. As part of the project Mr. Forbes and Mr. Henyey are doing some calculations on the detailed structure of a shell source of energy. The work is an extension of a project started some time ago in collaboration with Dr. Karl-Heinz Böhm.

Calculations concerning the stability of isothermal spheres were finished. Dr. Peter Sweet, of London University, will discuss the material.

Calculations for a general table of the equations of state of a degenerate gas were started by Hyron Spinrad.

David Wood started working on a computer (IBM 704) program for the analysis of light curves of eclipsing binaries. Starting with a highly simplified approach and gradually introducing complications he will endeavor to create a complete program for automatically deriving a least square solution for the elements.

L. G. HENYEY, *Chairman*

Lick Observatory, University of California, Mount Hamilton, California

Personnel. Dr. Marianne C. Bretz and James B. Gibson were appointed assistants on July 1, 1958. Arnold Klemola resigned his assistantship on September 16 to return to graduate study in Berkeley.

The Lick Observatory Fellows for 1958–59

were Charles Perry, George Preston, and Kenneth Widing. Hyron Spinrad was appointed Lick Fellow on February 1, 1959 when George Preston completed his work for the Ph.D. degree and left to become a Carnegie Fellow at the Mount Wilson Observatory.

Staff activities. Bidelman, Bretz, Kron, Mayall, Walker and Whitford attended the Tenth Assembly of International Astronomical Union in Moscow. Bidelman and Mayall attended the Paris Symposium on Radio Astronomy in August 1958. Kron attended the Conference on Image Tubes in London in September 1958. Jeffers represented the Observatory at the 50th Anniversary celebration of the Manuel Foster Observatory in Santiago, Chile in October 1958; this observatory in an outgrowth of the Mills expedition from Lick Observatory. Bidelman went on an observing expedition to the Bosque Alegré station of Cordoba Observatory during February-March 1959. Herbig served as visiting professor at Yerkes Observatory for six weeks in the spring of 1959. Mayall carried out spectroscopic observations at McDonald Observatory in March and April 1959.

Bidelman continued as editor of the *Publications of the Astronomical Society of the Pacific.* Shane continued as a member of the Board of Directors of the Association of Universities for Research in Astronomy (AURA), and served as president of the Board from December 1958.

Visitors. Astronomers from other places who came to the Observatory for a period of study or observational work included the following: Dr. Dean B. McLaughlin, University of Michigan, September 15–December 5; Dr. W. W. Morgan, Yerkes Observatory, October 15–December 15; Dr. Elizabeth Roemer, U. S. Naval Observatory, Flagstaff Station, October 18–30; Mr. Ulf Sinnerstad, Stockholm Observatory, May 1–30; Dr. E. Mendoza, Tonanzintla Observatory, May 25–July 25, 1959.

EQUIPMENT AND PHYSICAL PLANT

The 120-inch telescope. The figuring of the mirror was resumed by Hendrix and Cowan in July 1958. The Hartmann tests were carried out by Vasilevskis and Mayall; Balz, Mrs. Herbig, Gibson, and Klemola took part in the measurement and reduction. In August the mirror reached the quality of certain other large mirrors, with a Hartmann constant of 0.19, calculated by the conventional method, or 0.25 by the method which takes tangential measures into account. By December the coefficients by the two methods were 0.12 and 0.15 respectively.

During the winter season the support system was checked, and mirror tests made under various temperature conditions and at zenith distances up to 60°. The figure of the mirror is quite sensitive to temperature differences, but no appreciable change in figure with zenith distance could be detected; the support system functions well. In May 1959 local figuring was resumed, and it soon became evident that most of the apparent departures from a true paraboloid were comparable with the unavoidable distortions accompanying small residual temperature differences. It was therefore decided to aluminize the mirror, and a satisfactory coat was applied on June 24, 1959.

The engineering staff, under the supervision of D. J. Ludden, completed designs for the prime focus spectrograph and for most of the components of the coude spectrograph. The prime focus head was completed, the aluminizing tank completed and made vacuum tight, and the mounts for the No. 2 and No. 3 coude mirrors were installed and aligned with mirrors in place. The main frame for the coude spectrograph was installed in May, and on June 30 the mountings for the optical components were under construction. Regular operation with the 20-inch camera is scheduled for September 1959. The machine shop has been enlarged to handle construction of a large part of the remaining auxiliary instruments for the new telescope.

New construction. An additional apartment unit was added to the "New Dormitory" built in 1954–55. The new spring on the north slope was brought into service and provided an urgently needed supplement to the water supply during the season which followed the extremely low rainfall of the winter of 1958–59.

INSTRUMENTAL DEVELOPMENT

Image tubes. Walker, with the aid of a grant from the National Science Foundation, is designing and building an attachment that will allow an image tube of the Lallemand type to be used with the coude spectrograph of the 120-inch telescope. Kron is investigating improved methods of constructing and operating image tubes of the Lallemand type. The first objective is a demountable tube which will preserve the cathode at one end while the photographic plate

at the other end is removed from the evacuated space. This work is being supported by the Office of Naval Research. Both Walker and Kron visited Professor Lallemand's laboratory in Paris in the summer of 1958.

Plate measuring machine. A contract for the first phase of the construction of the automatic measuring equipment for astrographic plates was let in May 1959. After extensive correspondence and consultation with prospective contractors, carried on by Vasilevskis, the proposal from the Gaertner Scientific Corporation of Chicago was selected. The contract is financed by a grant from the National Science Foundation; a second grant, for the next phase, was received in June 1959. It is expected that the equipment will be completed and installed at Lick Observatory by June 1962.

The surveying and measuring equipment was planned primarily for automatic measurement of positions and magnitudes on 17 × 17-inch plates taken with the 20-inch Carnegie astrograph, and a possible similar southern astrograph, for determination of stellar proper motions with reference to external galaxies. The machine is expected to be so versatile, however, that it may be used for measurement of other plates, taken in the course of various programs at Lick Observatory or elsewhere.

SCIENTIFIC PROGRAM

Solar system. Jeffers photographed Mars with the 36-inch refractor during the opposition season in the fall of 1958. About 1800 exposures on 29 plates were obtained. The object was to secure a record for comparison with photographs made of previous oppositions, in order to assess surface changes. A preliminary report of these studies appeared in *Pub. A. S. P.* 70, 305, 1958. A photographically reproduced set of about 100 photographs of Mars covering the oppositions from 1939 to 1958 was prepared and circulated to those interested.

The comets which appeared during the year were photographed by Jeffers with the Crossley reflector. Special attention was given to the fainter ones. Comet 1956c (Wirtanen), which had two nuclei about 20″ apart, was photographed several times. Gibson assisted in the measurements for position, which are nearly up to date.

Double stars. Jeffers used the 36-inch refractor to obtain 103 additional double star plates, involving about 11,000 exposures. The measurement and reduction of this continuing series of plates is shared with Professor Ejnar Hertzsprung. About 600 measures have accumulated and are being prepared for publication.

The Index Catalogue of double stars being prepared by Jeffers is nearing completion. The catalogue will summarize essential data regarding known double stars north of −20°, and utilizes information in the punched-card catalogue of observations since 1927 completed about a year ago. The latter is being kept up to date, and late entries are to be included in the Index Catalogue. Much of the painstaking work in completing these two projects has been provided by Mrs. Frances Greeby; both projects have been supported by grants from the National Science Foundation.

Variable stars. Preston investigated the spectra of over 100 RR Lyrae variables with low dispersion. Near minimum light, variables of Bailey type *a* and *b* show hydrogen lines of the same strength as F4-F6 stars, but the metallic lines differ in strength by amounts up to one spectral class. The spectra range in appearance from normal F-type stars ("strong-line" objects) to extreme F-type subdwarfs ("weak-line" stars). The period-frequency distributions of the more extreme examples of these groups indicate that the RR Lyrae population near the sun differs from the similar population in globular clusters and in regions high above the galactic plane in that it contains many strong-line variables. The concentration of strong-line variables to the galactic plane is confirmed by comparison of period-frequency distributions in various regions of the galaxy. In addition, the strong-line variables appear to be relatively less concentrated to the galactic center. The solar motion and mean peculiar radial velocity of the weak-line variables resemble those of the globular clusters; those for the strong-line variables are intermediate between the values for halo and spiral arm objects.

Kron continued his program of photoelectric observations of RR Lyrae stars. Colors and magnitudes are obtained for both maximum and minimum light. About 75 per cent of the list of 54 stars has been completed.

Kron and Svolopoulos have analyzed their six-color photoelectric observations of 24 classical Cepheids and have evaluated the reddening of each by comparison with Kron's recently determined intrinsic colors of supergiants. The reddening found is not sufficient to bring the

galactic Cepheids into agreement with the very blue Cepheids in the Small Magellanic Cloud, reported by Gascoigne and Kron in 1953; the latter still appear to differ intrinsically from those in the Milky Way. The work has been published in *Pub. A. S. P.* **71**, 126, 1959.

Svolopoulos completed six-color photoelectric observations of 10 classical Cepheids, using the Tauchmann 22-inch reflector. The periods range from 1.9 days for SV Cassiopeiae to 17 days for Y Ophiuchi. For colors not affected by variations in hydrogen absorption, or blanketing by metallic lines, the magnitude range or amplitude for each star varied linearly with inverse wave length, as shown theoretically by Miss Hack. The amplitude in these "pure" colors shows a linear variation of amplitude with the logarithm of the period; there is a sharp separation, however, between Eggen types A and B and type C. The latter type stars show a smaller range than the former and are hotter and more luminous, in agreement with Sandage's results. Absolute dimensions were computed by the Wesselink method for four stars with good radial velocity data.

The short period variable VV Puppis (van Gent's star) was studied spectroscopically by Herbig with the Crossley reflector. The spectra show clearly that the variable is not an RR Lyrae star, but is a very peculiar eclipsing binary with a period of 100 minutes, the shortest known for any binary. The primary star (the only one visible in the spectrum) is a hot subdwarf with strong *H* and *He*II emission lines. The photometric behavior of VV Puppis indicates that it is an exaggerated example of the family of eclipsing binaries that includes DQ Herculis, UX Ursae Majoris, and RW Trianguli. The peculiar light curve can be explained by assuming a "hot zone" on one side of the larger, hotter star.

Walker and Herbig are observing RW Trianguli in a joint photoelectric and spectroscopic program. The light curve is of the Algol type, and resembles that of DQ Herculis and UX Ursae Majoris in showing an asymmetric rising branch. The total brightness of the system is also variable, the eclipse being deepest when the star is faint. Expansion of the brighter eclipsed component would explain the variable depth, but there is no corresponding change in the shape of the light curve. Ejection of luminous material, which material is only partially eclipsed, provides an alternative explanation. The streams of gas which surround such stars probably distort the light curve and render the normal interpretation of the geometrical elements unreliable.

Walker has observed a number of eclipses of DQ Herculis with the Crossley reflector and a 19-stage Lallemand photomultiplier tube. Observations were spaced in such a way that when they were combined with material from previous years, a definitive period for the 70-second variations was obtained. All observations since the discovery of the phenomenon in 1954 are represented by a preliminary period of 0.00082252083 days. The total number of cycles covered is 1,863,629. Further study of the light curves is in progress, and an improved value of both the 70-second period and the 4.5-hour period should result.

As a part of the international cooperative program for observing β Lyrae, organized by Walker and by Dr. Otto Struve of the Berkeley Department, David Wood of the Berkeley Department made three-color photoelectric measurements during a 22-day interval in June–July 1958. The two eclipses in this interval were not identical, but both were slightly asymmetric. In the *U-B* color the system was 0.13 mag. redder at primary eclipse and 0.07 mag. redder at secondary. For the *B-V* color the corresponding differences were 0.07 mag and 0.00 mag. redder. Svolopoulos obtained 50 spectrograms of β Lyrae with the Mills spectrograph as a part of the same cooperative program; these are being analyzed by Dr. Struve.

Galactic clusters. Walker is completing his discussion of the color-magnitude diagrams of five extremely young clusters. The work is based on observations previously made by him at the Mount Wilson Observatory. The photoelectric sequences used to calibrate the photographic photometry have been strengthened by further observations at the Crossley reflector. The work on IC 5146 is complete, and the material is in press. The B1 IV star, which illuminates the reflection nebula associated with the cluster, is on the main sequence, as are several stars near Ao. As in NGC 2264, M8, and the Orion nebula, later stars are above the main sequence and are presumably still in the contraction stage; an age of 3 million years is estimated. One Ao star appears to be younger than the rest and may be a future B star still in the contraction stage. A number of T-Tauri and late-type Orion variables were found.

Reductions are nearly complete for NGC 6611, and are in progress for IC 1805 and NGC 2244.

The next phase in Walker's investigations of young clusters consists of a three-color photometric study of the less luminous stars in NGC 2264 and the Orion nebula, extending to the faintest possible limit. A start has been made, using the Crossley reflector, and the stars in the Orion nebula on the Brun list down to visual magnitude 13 have been covered.

Vasilevskis continued the program of determining proper motions of stars in open clusters from plates made with 30-inch Thaw refractor at Allegheny Observatory. Plates taken by Trumpler about 40 years ago are compared with modern plates. Balz has made most of the measurements. In addition, plates of the cluster NGC 2264, taken at Lowell Observatory with a difference of epoch of almost 40 years, have been measured by Klemola and Balz.

Colors, spectrophotometry. Kron completed a six-color photoelectric study of supergiant stars of classes O9 to K5. Of the 139 stars used in the discussion, about half represented stars not previously observed on the six-color system. From two-color plots, reddening lines and normal or intrinsic colors were established for each type. Color excesses could then be assigned. The results appeared in *Pub. A. S. P.* 70, 561, 1958.

Stebbins and Kron's program of using the six-color observations to determine the color temperatures of stars has depended on calibrations and intercomparisons of ribbon-filament tungsten lamps. The brightness temperature of such a lamp as determined on a pyrometer calibrated by the U. S. Bureau of Standards now agrees with the value found in Kienle's laboratory in Heidelberg. The fundamental comparison between a lamp and the stars has been repeated, using an improved lamp and a new photomultiplier. The reductions are in progress and the final result is in sight.

Stellar spectroscopy. Herbig completed an extensive study of Be and Ae stars associated with nebulosity. The purpose was to see if these young objects could be identified as large-mass stars still in the process of gravitational contraction. Evolutionary calculations had indicated that there should be a number of such objects within observable distance. While some of the 26 peculiar stars studied showed characteristics that were consistent with this hypothesis, these properties could not be proven to be unique at the dispersion employed; other stars not associated with nebulosity showed similar peculiarities. The most persistent features were weak shells in one group of stars, and P Cygni-like line structure in a second group. Two new variable nebulae were found in the course of the investigation.

Herbig has continued spectroscopic observa- of M dwarfs in order to explore the ramifications of the proposal that the dMe stars are still in process of contraction, and owe their emission spectra and flare activity to this fact. All the known late-type members of the Hyades fainter than $M_{pg} = 12.0$ have now been observed; of these 18 stars, only the three faintest showed hydrogen emission, as would be expected under the hypothesis being tested. About a dozen of the faint M stars found recently by Williams and Blanco near the north galactic pole have also been observed.

Bidelman has advanced his program of observing the *Hα* region of the spectrum of supergiant stars of all classes. The object is a more thorough investigation of the correlation between *Hα* emission and luminosity that appears to exist for early type supergiants. For the northern sky, nearly all of known supergiants of luminosity classes Ia and Iab have been observed at a dispersion of 88 Å/mm. During a visit to Cordoba Observatory early in 1959, he was able to obtain similar observations for the brighter southern supergiants. Strong *Hα* emission was discovered in the spectra of HR 4169 (A0 Ia), HR 4511 (G0 Ia), and HR 6131 (B2 Ia). Other objects studied at the Cordoba Observatory included a few previously unrecognized supergiants of late type, the M-supergiant members of several galactic clusters (including the Kappa Crucis cluster), and a few members of the large open cluster NGC 3532.

The spectra of brighter southern stars of types G, K, and M, taken at the Lick Southern Station, have been inspected by Bidelman and Svolopoulos. They also examined all available spectrograms of early type sharp-line stars. A number of intermediate supergiants and peculiar stars were found: in particular, HR 6766, a G5 star which resembles HR 885 in showing no *CH* absorption, and HR 6870, a sharp line B or A star with simultaneously strong lines of *C*II, *Fe*II, and *Sr*II.

Svolopoulos, under Bidelman's direction, has nearly completed observations of the visual region of the spectrum of all stars fainter than $M_v = 6.5$ which are classified Mb in the *Henry*

Draper Catalogue. The object is a study of the relative frequencies of M, S, and M-S stars.

Svolopoulos has also assisted Bidelman in compiling a comprehensive list of all stars with spectra classified on the MK or MKK system. The list has about 10,000 entries thus far.

Walker has obtained spectra of the latest red giants in several galactic clusters, using the 36-inch refractor. The purpose was to strengthen the absolute magnitude calibration of MK luminosity classes for late M giants. No very late-type M giants were found. The latest-type star in M11, Küstner No. 143, was classified M 2.5 III by Bidelman; Küstner No. 751 in NGC 7789 is near gM1. The measured *B-V* colors of both are in agreement with those expected from the classification. The previous Burbidge-Sandage classification of the latter star as K3–4 III had led to doubt as to whether these cluster members followed the normal spectrum-color relation.

Mayall has nearly completed his program of obtaining spectrograms of faint planetary nebulae, a joint undertaking with Dr. R. Minkowski of Mount Wilson and Palomar Observatories. Ten spectra were added during the year.

Dr. E. Mendoza, of Tonanzintla Observatory, collaborated with Herbig in observing the spectrum of two supernovae: that in NGC 7331, and one in a faint galaxy near $13^h\ 06^m$, $+4°$.

Dr. Dean B. McLaughlin of the University of Michigan studied the spectra of novae and supernovae in the Lick files. The spectrum of the supernova of 1954 in NGC 4214 proved to differ considerably from the early stages of other supernovae of type I. Several features could be interpreted as the absorption lines of a B-type spectrum without hydrogen lines, with a velocity shift of -5000 km/sec. Absorption-like features in other type I supernovae may be interpreted in a similar manner.

Galaxies. Shane and Wirtanen have virtually completed the program of counting galaxies on the plates made with the 20-inch astrograph. The results for four of the nine areas are in press. The material in these four areas was used for a redetermination of the absorption in the galaxy. The amount found, 0.43 magnitudes photographic, was the same at both galactic poles; it is substantially larger than the generally accepted value. After the results on the three remaining areas have been prepared for press, a standardization program covering all areas is planned, in order to be able to reduce the counts to a common limiting magnitude.

Mayall has continued to observe galaxies for redshift with the nebular spectrograph at the Crossley reflector. The year's results include two in the Coma cluster, five in the Virgo cluster, 11 in the brighter Fornax cluster, and 11 in the general field.

Dr. W. W. Morgan of Yerkes Observatory studied photographs of galaxies as a means of extending his scheme of classification which considers the relation between the form and the stellar content as revealed by the spectrum.

Miscellaneous. Herbig made some calculations designed to explore the possibility that the nebulosity around Spica, observed in the wave lengths 1225–1350 Å by the Naval Research Laboratory rocket group, could be due to resonance scattering by hydrogen molecules near the star. He reached the conclusion that under reasonable assumptions H_2 scattering would be two orders of magnitude fainter than the reported flux from the nebulosity.

A. E. WHITFORD, *Director*

Louisiana State University Observatory, Baton Rouge, Louisiana

Personnel. Dr. Pierre Demarque has been appointed Assistant Professor of Physics and Astronomy, September 1959. Dr. Demarque has recently completed a dissertation at the David Dunlap Observatory on the structure of subdwarf stars. Dr. Kenneth M. Yoss resigned in June 1959 to take a position at Mount Holyoke College, South Hadley, Massachusetts. The teaching assistants for the year were John Nelson Hubbell, Jr. and Fred E. Ellis. Research assistants were Jonas T. Holdeman and Lawrence Nicola.

Research. Yoss has found a number of late type giants with weak *CN* absorption from Michigan Curtis Schmidt objective prism spectra. He is deriving space velocities for these suspected high velocity stars from spectrum plates obtained with Mt. Wilson 60-inch reflector. This work is being sponsored by the National Science Foundation.

Holdeman is converting a conventional Leeds and Northrup microphotometer to a direct intensity instrument by means of a function generator. This instrument will be used to reduce

the Yoss objective prism plates. This work is being sponsored by the Research Corporation.

Grenchik has attempted various concentrations of helium in white dwarf atmospheres to determine the effect on the hydrogen line profiles. Previous work by Grenchik with pure hydrogen atmospheres predicted broader lines than are observed. Work by Nicola in a master's thesis showed that increasing helium concentrations had a tendency to further broaden the lines. The Esso Research Labs have made available their IBM 650 for these calculations.

Teaching. Enrollment for the elementary courses was in excess of 600. The advanced classes of Spherical Astronomy, Introduction to Solar System Astrophysics and Astronomical Photometry had a total enrollment of about 25. Masters' degrees in Physics with an Astronomy thesis were granted to William Ellerbe and Lawrence Nicola.

Building Plans. Bids will be submitted September 1959 on an extension to Nicholson Hall for increased space for the department of Physics and Astronomy. Astronomy will obtain increased research space, an advanced lab, three elementary labs with dark rooms and improved observing terrace facilities. An alternate in the building plan will be a planetarium with a 30-foot dome.

Miscellaneous. The 12½-inch reflector has been mounted on the west observing terrace. The objective prism for the Schmidt has been received and used in the photometry lab.

The observatory was open four nights in the fall, four nights in the spring and two in the summer. The total attendance was approximately 1500. Graduate assistants and majors took part in the talks and demonstrations.

Visitors during the year were J. Allen Hynek and Karl G. Henize of the Smithsonian Astrophysical Observatory and Armin J. Deutsch of the Mt. Wilson and Palomar Observatories.

RAYMOND T. GRENCHIK, *in charge*

Lowell Observatory, Flagstaff, Arizona

Personnel. E. C. Slipher resigned as acting director and John S. Hall became director of the observatory on September 1, 1958.

Additions to the staff were Kenneth L. Hallam, L. W. Fredrick and Marjorie A. Korner. Guest investigators were G. and A. de Vaucouleurs, W. A. Baum, W. Kent Ford, Jr., M. A. Tuve, T. E. Houck, Harold F. Weaver, David Wood, Hyron Spinrad and David Steinmetz. Those on temporary appointment were Robert Neville, Edgar Eberhard, Ann Geoffrion, and John Kirk.

Physical Plant. Negotiations were continued between representatives of Lowell, Ohio State and Ohio Wesleyan in an effort to find a mutually satisfactory arrangement by which the Perkins Reflector might be moved to the Flagstaff area and used jointly by the three observatories.

An excellent site 13 miles southeast of Flagstaff in a restricted watershed region has been earmarked by the Forest Service for the Perkins telescope. Comparative seeing tests made mostly by Eberhard on more than 20 nights have demonstrated that this site is at least as good as that near the 24-inch telescope on Mars Hill.

Construction was initiated to provide housing on the grounds of the observatory for the 24-inch Morgan reflector and to provide for associated darkroom and laboratory facilities as well as modest living quarters for an observer. The telescope was donated to the Lowell Observatory by Ben O. Morgan of Odessa, Texas in 1956. In March 1959 an agreement between the Carnegie Institution of Washington and the Lowell Observatory was signed by which this telescope is to be devoted almost exclusively to work being carried on by the Carnegie Image Tube Committee. A portion of the total cost of moving the telescope and of the associated housing is to be provided by Carnegie and NSF image tube project funds. Plans have been made to move the telescope to Flagstaff during September 1959.

Planetary Programs. E. C. Slipher and Robert Neville obtained more than 5000 photographs of Mars with the 24-inch refractor during the 1958 opposition. Slipher, on behalf of the Mars Committee, has prepared a report summarizing the observations made during the 1956 opposition.

William M. Sinton continued infrared studies of the planets. An infra-red spectrometer was fitted with an extremely sensitive lead-sulphide cell and in October, 1958 it was used on the 200-inch Hale telescope at Palomar to obtain spectra of Mars in the range 1–4 μ. In the spectra of dark areas of the planet three bands near 3.5 μ appeared. Similar bands are also found in terrestrial plants and one of the bands appears to be produced by carbohydrate molecules. These spectra yield strong evidence of vegetation in the dark areas of Mars.

An infrared pyrometer for planetary temperature measurements was completed by Sinton with the help of an NSF grant, and has been employed on the 42-inch Lowell reflector. A program of mapping of lunar isotherms has been started. Maps of isotherms are being made at different phases except near new moon where there is insufficient energy. Observations for 8 maps have been made. Regular temperature measurements of Venus were started by Sinton in January for the purpose of finding any phase effect.

Sinton has determined the phase variation of Uranus and Neptune from the extensive photoelectric observations made in the program of solar variation. A determination of the albedos of these planets in UBV colors was also made from these data. This discussion is given in *Lowell Obs. Bull.* No. 95. Observations have been made to derive albedos in the red and infrared as well.

Solar Variations. The solar variations project has been continued with financial support by the Air Force. A report in which an increase in brightness of Uranus and Neptune (and presumably the sun) is found, has been published as *Lowell Obs. Bull.* No. 96. Those working on this project were H. L. Johnson, B. Iriarte, and A. Seeglitz.

The 1958–59 observations of Uranus and Neptune have been completed and reduced. The new mean values that have been obtained for this season are listed in Table I along with

TABLE I. BLUE MAGNITUDE, B, FOR THE TWO PLANETS

Season	Uranus	Neptune
1952–53	6.070	8.269
1953–54	6.072	8.266
1954–55	6.075	8.251
1955–56	6.056	8.245
1956–57	6.060	8.241
1957–58	6.056	8.235
1958–59	6.025	8.248

the previous values from *Lowell Obs. Bull.*, No. 96. The planets continue to be brighter than they were at the time this project was initiated, but there may be some indication that the rate of increase has dropped.

Proper Motion Program. H. L. Giclas, assisted by Robert Burnham, Jr. and Charles Slaughter, have completed work on the first 50 regions of the 13-inch proper motion survey. This represents about one-quarter of the plates that cover the northern hemisphere. Over 8300 measurements for motion were made, and 2272 stars having motion $\geq 0''.27$/year were retained for publication. After the elimination of duplicate entries, 1783 different stars remain, of which 1105 or 62% will be newly listed ones. Eight stars having motion $>1''.0$/year and 192 with motions $>0''.5$/year have so far been discovered. Twenty-three white dwarf suspects are listed, 19 new pairs of stars with common motion, and 10 additional pairs added by finding a second fainter star with motion common to an already known proper motion star. Two comets, 296 minor planets and 176 variable stars have been marked on the plates. This program has been, in part, supported by an NSF grant.

Comets. Two comets, Burnham-Slaughter 1958e and Slaughter-Burnham 1959a, were discovered on the proper motion program by Rober Burnham, Jr. and Charles Slaughter respectively. Miss Roemer of the U. S. Naval Observatory has found that the orbit for Comet 1959a is periodic with $P = 11.64$ years, a low inclination of $i = 8°.2$, and $e = 0.50$. It is, therefore, a newly discovered member of the Jupiter family of comets. Giclas has measured the accurate Lowell positions for the comets and complied with several requests for accurate minor planet positions.

Open Cluster Project. The program of the observation of open clusters, initiated by H. L. Johnson and supported in part by ONR, is well started. The photoelectric observations are complete or nearly complete in 53 clusters. Photographic plates (taken by Dr. A. A. Hoag of the Naval Observatory) have been measured for 31 clusters.

An analogue computor, designed by H. L. Johnson for the reduction of UBV observations, has been constructed. A description of this computer has been published in *Lowell Obs. Bull.*, No. 100. It has been used to reduce the photoelectric observations in the 53 open clusters and for the reduction of other UBV observations.

Those working on this project were H. L. Johnson, B. Iriarte, K. L. Hallam, D. Hart, and A. Seeglitz.

Image Tube Project. During the year a comparison between aided and unaided photography was made using three types of image tubes. These included one barrier-membrane tube, two cascaded tubes and a simple converter with a mica-window output. Some of these comparisons were made at the 40-inch reflector of the

U. S. Naval Observatory and the others at the 24-inch Lowell refractor. Those participating in these tests were W. A. Baum, W. K. Ford, Jr., John S. Hall and M. A. Tuve. Beginning in June T. E. Houck and L. W. Fredrick became actively engaged in this project.

The barrier-membrane tube had low cathode sensitivity and yielded results only slightly better than direct photography. With tubes of the other two types it was possible to reach the same limiting magnitudes as by unaided photography in 1/30 the exposure time. Stars of visual magnitude 21 were detected with a cascaded tube on the 40-inch telescope. By taking advantage of momentary instants of good seeing, it was possible to separate clearly several double stars which could not be separated by direct photography under the same conditions. Motion pictures of double stars down to magnitude 7.5 were secured with the 24-inch refractor operated at $f/80$. The resolution of these tubes was in the range of 10 to 15 line pairs/mm and the useful field was only about 6 mm at the cathode.

Other Programs. The Lowell 21-inch and 42-inch reflectors and the 40-inch reflector of the U. S. Naval Observatory were used by Kenneth L. Hallam for 7-color photoelectric photometry of 92 galactic OB stars down to visual magnitude 11.5 for the investigation of the wavelength dependence of interstellar extinction in the associations VI Cyg, I Per, I Ori, I Mon, and elsewhere.

Photoelectric observations in the B-V system have been made by B. Iriarte of 48 blue stars at high galactic latitudes. Some interesting features in the color diagram of these stars were found. Photoelectric observations of faint blue stars starting at $V = 15$ are planned for this year.

Four-color observations (U, B, V, and Infrared) have been obtained by H. L. Johnson for the eclipsing variable, γ Leonis.

W. F. Weaver began a program of the photoelectric observations at the 21-inch of northern Cepheid variable stars. The guest investigators were H. F. Weaver, D. Steinmetz, D. Wood, and H. Spinrad.

Lowell Observatory Bulletins. The policy of publishing Lowell Bulletins has been renewed. During the report period bulletins 89–100 of Vol. IV were distributed together with an index to Vol. III.

JOHN S. HALL, *Director*

The Observatories of the University of Michigan, Ann Arbor and Pontiac, Mich.

THE OBSERVATORY, Ann Arbor, Michigan

PERSONNEL

Dr. Kenneth M. Yoss of Louisiana State University spent the summer of 1958 as guest investigator making observations with the Schmidt telescope. In August 1958 Mr. Adolph Foerg joined the staff as a full-time Instrument Maker. Dr. Miller continued to serve part-time as Director of the University of Michigan Academic Year Institute sponsored by the National Science Foundation and part-time as assistant for sponsored research to the Dean of the Literary College. Dr. McLaughlin was on sabbatical leave the first semester, spending the time in research at the Lick and Mt. Wilson Observatories. Dr. William E. Howard III joined the staff in the spring of 1959 devoting half-time to research with the radio astronomy project and half-time to teaching. Dr. J. L. Sersic, of the Cordoba Observatory, spent two months working with the isophotometers. The following graduate students served as part-time teaching and research assistants during the past year: Stephen M. Adler, Charles Cowley, Von Del Chamberlain, Frank C. Jettner, Jr., Amalia Kott, S. S. Kumar, E. K. Lee, J. Paul Mutschlecner, T. P. Stecher, R. G. Tull, E. K. L. Upton, and Lloyd Wackerling.

INSTRUMENTAL

Francis C. McMath Reflector. During the course of the year, a new polar axis and driving system for the Francis C. McMath 24-inch reflecting telescope were constructed in the Observatory shop. Formerly in use at the McMath-Hulbert Observatory, the telescope is being re-located at the Portage Lake Observatory in a new building now under construction. The installation should be completed by the fall of 1959. Under the direction of Dr. Liller, Mr. Robert Tull has designed a new photoelectric spectrophotometer for the 24-inch telescope, and thanks to a grant from the Rackham School of Graduate Studies, its construction will begin in the summer of 1959. A novel feature of this instrument is that the intensity at a given wave length is continually compared with the intensity at a standard wave length. This feature should lead to improvement in the precision of relative spectrophotometry.

Radio Astronomy Project. The 85-foot radio telescope, fabricated by the Blaw-Knox Company, has been erected, aligned and tested. It is in operating condition and observations have been made; however, a number of electrical and mechanical items remain to be completed during the summer of 1959. An Ewen-Knight traveling-wave-tube radiometer, receiving over the spectrum from 7500 Mc/s to 8500 Mc/s, has been installed in the telescope. Ultimate performance of this Dicke-type, ferrite-switched radiometer with the 85-foot telescope should permit the detection of incident flux densities of less than 10^{-26} watts per square meter per cycle per second. Preliminary measurements on a radio source in the above frequency band indicate that the antenna pencil beamwidth is less than 6 minutes of arc at the half-intensity level, in accordance with expectation. However, much detailed work is required to evaluate fully the antenna capability. For this purpose the 16,000 Mc/s Dicke-type radiometer is being installed in the 85-foot telescope to check the reflector at a frequency above the design value.

A new sweep-frequency receiver covering the spectrum from 2000 Mc/s to 4000 Mc/s with adjustable radio-frequency band widths up to 5 Mc/s has now been installed in the 28-foot radio telescope and regular daily operation will begin in the summer of 1959. The receiver was constructed in the laboratories of the International Telephone and Telegraph Company at Fort Wayne, Indiana.

The expanding needs of the program have led to the construction by the University of a second building at the Radio Astronomy Observatory. It has a floor space of 1200 square feet and its primary function is to house the 85-foot telescope controls, receiver output circuits, recorders, test equipment, etc.

Overall supervision of the radio astronomy project is in the hands of F. T. Haddock, Professor of Astronomy and of Electrical Engineering. He is assisted by Dr. A. H. Barrett, Research Associate, who is responsible for putting the 85-foot telescope into operation. The project is a joint effort of the Departments of Electrical Engineering and Astronomy. Funds for equipment and technical support continue to be generously provided by the Office of Naval Research under Contract Nonr-1224(16), Project NR 371-390.

OBSERVING PROGRAMS

37-inch Reflector. During the twelve months ending June 15, 1959, inclusive, 194 spectrograms were taken with the 37-inch reflector, distributed as follows:

Be stars	66
Composite spectra	21
RS Ophiuchi	29
VV Cephei	16
Nebulae	25
Peculiar spectra	13
Miscellaneous	24

Curtis-Schmidt Reflector. Mr. Peter Boyce has obtained blue and red plates of several edge-on galaxies in classes Sa to Sc. The material will be analyzed with the isophotometer in connection with a study of the light distribution in the optical coronas of these objects. Dr. Kenneth M. Yoss, of Louisiana State University, again spent two months at the Observatory in the summer of 1958 as a guest investigator, while carrying out observations with the Schmidt telescope and utilizing the Schmidt plate collection. Yoss, Stecher and Johnson carried out a spectrophotometric study of objective-prism spectrograms of RS Ophiuchi.

Radio Astronomy Project. The 100 Mc/s to 600 Mc/s sweep-frequency receivers connected to the 28-foot radio telescope have been continued in daily operation for solar observation during the past year. The 16,000 Mc/s receiver has been removed from solar recording and installed in the 85-foot radio telescope.

SUMMARY OF RESEARCH WORK

Be Stars. Measures of the spectra of several of these objects have been continued by McLaughlin. π Aquarii, after a period of quiescence for several years, has resumed conspicuous V/R variations. The northern component of 8 Lacertae has lost all of its emission lines with the exception of $H\alpha$. During sabbatical leave in the first semester, McLaughlin measured most of the Lick Observatory spectrograms of Be stars that are on the Ann Arbor program. Kumar has assisted in the reductions of those measured. Numerous Mt. Wilson-Palomar plates of the same stars were measured, including some coude spectra.

Novae and Supernovae. While on a sabbatical leave during the first semester, McLaughlin made many additional measures on the spectra of several novae observed at Lick and Mt.

Wilson-Palomar Observatories. Numerous spectra of supernovae were also studied. Most of the Lick spectrograms were measured and traced with the Moll microphotometer and numerous Mt. Wilson-Palomar plates were measured. Special attention was paid to minima that might be interpreted as absorption lines. The spectrum of the supernova of 1954 in the irregular galaxy NGC 4214 differed considerably from most supernovae of Type I in that it contained several minima that appear like wide absorption lines. The pattern is tentatively interpreted as a B-type spectrum, with practically no hydrogen lines, and shifted by $-5{,}000$ km/sec.

VV Cephei. Peery has completed radial velocity measurements of spectrograms of VV Cephei, covering the interval 1932–58, and has obtained preliminary orbital elements.

Theory of Stellar Atmospheres. In the original formulation of the Kolb theory as applied by Jugaku, Elste and Aller, and subsequently by others, to the interpretation of line profiles of hydrogen in stellar atmospheres, the non-adiabatic effects were handled in a very approximate fashion. More recently, Kolb and Griem have eliminated this shortcoming in the theory and have given an exact treatment of the problem of hydrogen line broadening. Jugaku and Aller have applied the improved Kolb-Griem theory to the calculation of the profiles of the $H\gamma$ line in B-star spectra, using the same atmospheric models as have been employed previously in the analyses of the spectra of B-stars. The improved theory gives slightly deeper profiles indicating that when an agreement between theory and observation is obtained, yet lower surface gravities are required than had been indicated previously. This result is satisfactory in that the surface gravities now come out closer to the values indicated from the data of the eclipsing binaries for these B-stars.

Solar Abundances. Completion of the investigation of solar abundances by Goldberg, Muller and Aller has been delayed pending the incorporation of a large amount of new data on f-values, which has recently been published both in the United States and abroad. Preparation of the revised results for publication is now essentially complete.

Under a grant from the National Science Foundation, Aller is employing new observations by Mohler with the vacuum spectrograph for an investigation of the spectral lines of certain rare and strategic elements in the solar atmosphere. So far the observational program for lead, gold, ytterbium, zirconium, ruthenium, columbium, rhodium, silver, indium, lithium, and beryllium is essentially completed. The reductions are necessarily slow since separate theoretical analyses have to be carried out for each individual line. To date, only one representative calculation for lead has been carried out, which suggests abundances slightly greater than those found in the Goldberg-Muller-Aller program. In this analysis, the intensity at the center of the sun's disk and the limb darkening are used in order to establish the influence and magnitude of sources of continuous absorption other than that of the negative hydrogen ion. It turns out that the absorption produced by the far wings of moderately strong lines is more important than the effects of many numerous weak lines closely overlapping one another.

Stellar Structure. Upton, Mutschlecner, Adler, Tull, and Kumar have collaborated with Aller in investigating the problem of a star in which hydrogen has been replaced by helium, such as Popper's helium star, Bidelman's star, HD 160641, and several others. Three phases in the development of the star have been considered: a contractional phase, a phase during which helium is burned into carbon, oxygen and neon in a convective core, and an advanced stage in which the core is exhausted and the energy is produced by core contraction and by the burning of helium into carbon in a thin shell. Detailed calculations have so far been carried out only for a star of one solar mass, the idea being to compare the results with the known data for the stars on the horizontal branch in the color magnitude array for globular clusters and for the nuclei of planetary nebulae.

A pure helium star which settles down to burning helium into carbon has a central temperature of about 140,000,000° if it has a mass about equal to that of the sun. At the edge of the convective core the temperature is around 100,000,000°. As the star evolves, the temperature in the core rises relatively slightly, and when the helium in the core is virtually exhausted the temperature has risen only to about 180,000,000°. Eventually a shell source develops as the convective core becomes thoroughly carbonized or converted into oxygen and neon. Compared with the corresponding phase in a hydrogen burning star the shell burning phase is relatively brief and the star brightens only

slightly before the core goes degenerate. The calculations have not been pursued beyond the point where degeneracy sets in at the core, but it appears that the history of the star thereafter depends critically upon the mass. If the mass is substantially greater than that of the sun, the outer envelope escapes into space and we may get essentially the Wolf-Rayet star type of phenomena. If the mass is small, the entire star may quietly settle down towards a white dwarf phase.

The equilibrium configuration at the onset of helium burning corresponds to a point that lies considerably to the left of the position of the star in the corresponding hydrogen burning main sequence. The luminosity of the star changes relatively slightly during its subsequent evolution. The phases following upon the exhaustion of the helium core are relatively short-lived before the final degeneracy sets in. In other words, there is no great increase in luminosity during the evolution into the analogue of the giant stage.

On the basis of the calculations so far carried out, it would appear that a helium star of one solar mass can build helium into neon but cannot proceed to build elements very far beyond this point. No detailed studies of the late evolutionary stages of more massive stars have been attempted, but it does appear that for a star whose mass is several times that of the sun the temperature in the core could rise to a sufficiently high value to permit the attainment of the equilibrium configuration, at which point iron can be formed in quantity. Some of these phases will be investigated in more detail.

Gaseous Nebulae. Reductions of the photoelectric scanner spectral tracings of planetary nebulae obtained by Liller and Aller at Mt. Wilson in 1956 have been continued. The results confirm Aller's measurements made twenty years ago at the Lick Observatory by photographic photometry to within the limits of error of the latter.

On the assumption that the higher levels in the carbon ions, *C*II, *C*III, and *C*IV, can be treated as hydrogenic, the line intensities in the recombination spectra of ionized carbon have been investigated. The method employed is very similar to that used by Mathis for the helium lines in the Orion nebula and planetaries. Calculations have been carried out for the recombinations of singly-ionized carbon, doubly-ionized carbon and trebly-ionized carbon in a number of gaseous nebulae. The approximations employed appear to lead to an upper limit to the abundance of carbon, but they do indicate that carbon and oxygen are of comparable abundance, although oxygen is actually more abundant than carbon. Further refinements in the calculations will entail very extensive calculations with improved wave functions.

Liller and Aller have revised their estimates for the composition of the Orion nebula; the study is based partly on photometric measurements obtained with the photoelectric scanner and on some of the older photographic work. Very good agreement is found between the chemical composition of the nebula and stars formed from it.

Applications of the Stromgren theory to several ions such as oxygen, argon and neon in NGC 6572 have been attempted in an effort to study the spatial distribution of the ionic radiations and to improve the estimates of the concentrations of these particular elements in this nebula. The effects of the interlocking of the continua of the various ions suggests that it may be necessary to carry out extensive numerical integrations.

Satellite Astronomy. Two contracts have been entered into with the National Aeronautics and Space Administration for preliminary design studies leading towards the conduct of astronomical observations from artificial satellites and space probes. Haddock has begun planning and design on galactic and solar burst sweep-frequency radio receivers at frequencies below 30 Mc/s. Goldberg and Liller are collaborating in the initiation of design work on scanning spectrometers for the solar ultraviolet region 100–3000 angstroms. As a basis for estimating the intensity of solar ultraviolet radiation, Aller and Boury have examined various models that have been proposed for the solar chromosphere. A final mean model has been computed to agree with the radio observations obtained and compiled by Haddock. This model agrees closely with that of Piddington and less closely with the model proposed by Shklovsky and Kononovich. Aller has also attempted to predict some of the properties of ultraviolet stellar radiation, particularly the intensities of Lyman-α and the ionized magnesium lines at λ2800 along the spectral sequence, as well as the extinction of starlight by interstellar neutral hydrogen and helium.

Miscellaneous. Under a fellowship from the Consejo Nacional de Investigaciones (Argentina), Dr. J. L. Sersic, from Cordoba Observatory, spent two months working with the isophotometers. Isophotal contours were traced for twenty-two southern galaxies of several types. The reduction and interpretation of the same will be achieved next year at Cordoba.

LEO GOLDBERG, *Director*

McMATH-HULBERT OBSERVATORY, Lake Angelus, Pontiac, Michigan

PERSONNEL

As in recent years, Dr. McMath continued to give much of his time to problems connected with the Association of Universities for Research in Astronomy, Inc., and the creation of the Kitt Peak National Astronomical Observatory. In December, 1958, Dr. McMath relinquished the Presidency to Dr. C. D. Shane and became Chairman of the Board of Directors of the corporation.

On 1958, September 13, Dr. Keith Pierce resigned his position as Associate Professor of Astronomy, assigned to the McMath-Hulbert Observatory, to accept the Associate Directorship of AURA, with special duties in connection with the large solar telescope being designed for the new observatory. Dr. Helen Dodson Prince visited all of the major solar observatories in Western Europe during the months of March and April to obtain additional data for use in the reduction of IGY observations.

The term appointment of Mr. Robert Gouin as special assistant in the observatory's terrestrial magnetism and ionospheric recording program ended in October 1958. Gouin was replaced for one month, in January, 1959, by Mr. Bernard Adams, and later by Mr. Fred Stewart, who continued in the position throughout the term covered by this report. The student observing assistants during the months of July and August were Messrs. Canfield, Martens, Moore and Williams.

INSTRUMENTAL

The new densitometer-isophotometer was placed in operation in July, 1958. It has been operated almost continuously since that time. An important fraction of the operation of the instrument has been devoted to the development of new techniques of recording. A number of isodensity curves of the calcium solar plage regions have been made for the purpose of comparison with the visual estimations of plage areas. Approximately 250 tracings have been made as part of a catalog of the spectra of solar flares that have been obtained with the McGregor solar tower and the vacuum spectrograph. At the request of Dr. R. Tousey and Mr. J. D. Purcell of the Naval Research Laboratory, isodensity tracings have been made of their successful Lyman-α photographs of the disk of the sun, obtained on a rocket flight on April 13. Mr. Purcell assisted in the production of these tracings.

The maintenance of the special receivers for the recording of cosmic noise absorption and sudden enhancement of atmospherics has been an extremely heavy burden. The major part of the maintenance difficulties arises from overestimations of the capabilities of modern vacuum tubes. The circuitry is under study in an attempt to eliminate these sources of trouble.

A photoelectric dome control was installed on the Lyot photoheliograph. Small changes were made in the circuitry of the Lyot photoheliograph which have effectively removed some slight residual instabilities in its operation.

Trials of a new photographic technique, introduced to us by Mr. Richard C. Colton of the Eastman-Kodak Company, have been made in the 50-foot tower telescope. The new technique provides the best pictures of the sun, made with ultraviolet light, that we have yet obtained. Comparison of the structures visible on the new pictures and the details visible on the calcium spectroheliograms will be undertaken.

Changes of major importance were required in the McGregor tower telescope or the vacuum spectrograph. The declination driving system of the McGregor telescope was improved to make it more flexible and more precise. The present declination drive provides a wide range of speeds and has markedly improved the convenience and precision of the declination guiding. The complete vacuum sealing system of the vacuum spectrograph is being overhauled and reconditioned, after functioning for four years without difficulty.

OBSERVING PROGRAMS

The Lyot Photoheliograph. The Lyot photoheliograph has been in operation on every possible clear moment during the past year. The instrument has been modified with a view to

improving the already excellent records it has made of solar activity. Exposure times have been shortened from 4 seconds to a fraction of a second by using a more suitable emulsion than that recommended by the solar committee of the IGY. A photoelectric control of the dome has been added to the instrument to circumvent oversight on the part of the observer. The instrument has operated essentially without difficulty, taking pictures at a rate of two per minute during all clear daylight hours for the past year. In addition, nearly continuous visual observation of the sun with the Lyot photoheliograph has been maintained.

50-foot Tower Telescope. July 1, 1958 to January 1, 1959 were the last six months of the International Geophysical Year. This was a time of slow decline in solar activity from the very high maximum, as measured by the number of sunspots, in the early part of 1958. The 50-foot tower telescope was used for observation on 302 days. The program continues to assign a large part of the available observing time to the production of spectroheliograms spaced accurately, in small increments of wave length, across significant solar lines. The *Hα* and K lines of the solar spectrum are most frequently used in this procedure.

More than 250 spectra of flares and related phenomena, covering the wave length region from 6600 to 3600Å, were obtained with the Wadsworth spectrograph.

The observations made in the 50-foot tower telescope contributed to the following programs:

1. The recording of the complete solar disk on a scale such that the diameter of the sun is equal to 17 mm. These daily surveys are made principally with the *Hα* and K spectral lines.

2. Studies of the development of flares, as revealed by the spectroheliograms obtained at small wave length intervals spaced from the centers of the *Hα* and K lines.

3. The photography of flare spectra from *Hα* to approximately 3500Å.

4. The terrestrial effects of flares as shown by shortwave fades (5 Mc/s); cosmic noise absorption (18 Mc/s); sudden enhancement of atmospherics (27 Kc/s); and by variations in the total intensity and declination components of the earth's magnetic field.

5. The photography of the Ellerman solar hydrogen bomb.

McGregor Solar Tower Telescope. The McGregor solar tower telescope and vacuum spectroscope were in use on approximately 170 days. Observations were obtained on the following programs:

1. The production of direct photoelectric tracings:

a. Of the hydrogen lines for the purpose of establishing a mean value for the profiles of these important solar features.

b. To be used for the determination of the relative chemical abundances of selected elements on the sun.

c. For the experimental determination of absorption coefficients from selected pairs of spectral lines.

2. Photography of narrow regions of the spectrum, generally centered at *Hα*, *Mg* $b_{1,2,3,4}$ of K. When such photographs were made of flares, these observations were often carried out simultaneously with spectral and spectroheliographic observations in the 50-foot tower telescope.

3. Visual, photographic, and photoelectric observation of the Ellerman solar hydrogen bomb. This program was carried out in close conjunction with the 50-foot solar tower telescope.

Snow Telescope. As in past years, the programs of the Snow telescope have been closely integrated with the programs at Lake Angelus. During the time covered by this report, the program of the Snow telescope was almost exclusively the production of observations for the derivation of abundances, in support of the McGregor solar tower program. The Snow telescope observations have been especially valuable because of the increased ultraviolet transparency of the atmosphere over Mt. Wilson in comparison with that over Lake Angelus. In addition to the direct recording of spectral line profiles, drift curves of the sun at selected positions in the ultraviolet have been obtained. These are essential parts of the data required for the determination of chemical abundances in the sun's atmosphere.

SUMMARY OF RESEARCH WORK

Lyot Photoheliograph. Patrol films made with this instrument have been completely measured and the results of the measurements reported to the three World Data Centers for the period

covered by the International Geophysical Year. This is one of the few patrol instruments used during the IGY for the photometric measurement of solar flares. Except for revision for omissions and the detection of errors, this work is now complete.

A very large amount of staff time has been spent in observing, measuring and reporting data for the International Geophysical Year. The observations of plages, flares (obtained principally with the Lyot photoheliograph), ionospheric disturbances, and the equipment of the 50-foot tower telescope, have been, and are continuing to be, reported to world warning centers on both a daily and a monthly schedule.

McGregor Solar Tower Telescope. The Ellerman hydrogen bombs continued this year, as in the past year, to be objects of intensive study. The results of many of the first observations have already been reported. There is a serious gap in the observations by means of direct photography. An attempt is being made to supply these very important, but missing, observational data.

The long job of reduction of the more than 300 flare spectra obtained with the vacuum solar spectroscope is being continued as part of the International Geophysical Cooperation program.

Reduction and interpretation of the tracings made on the abundance program are being carried forward in Ann Arbor by Aller and his students. Some additional tracings are required on this program and are being obtained. Some preliminary and somewhat unsatisfactory maps of the solar spectrum of necessity have been used in the abundance measurements. It is hoped that these tracings of inferior quality can be replaced with improved recordings during the present observing season.

In cooperation with Dr. Walter Mitchell, of Ohio State University and the Perkins Observatory, an extensive program, leading to the publication of the direct photoelectric tracings made with the vacuum spectroscope as an atlas of the normal solar spectrum, is under way. As part of this program Dr. Mitchell has completely surveyed the existing ultraviolet maps and has prepared a program of observation which he will shortly undertake.

Intercomparison of 21 cm Solar Maps With 3933A (Calcium) Spectroheliograms. Isophotal maps of 21 cm emission from the solar disk, made at the Commonwealth Scientific Industrial and Research Organization, Sydney, Australia, for twenty-one days in the interval November 24, 1957 to January 16, 1958, were compared with calcium spectroheliograms made at the McMath-Hulbert Observatory. The centers of enhanced 21 cm emission agreed closely in position and extent with the calcium plages. For the days studied, the maximum intensity the 21 cm region was proportional to the maximum intensity of the calcium plages, except when major flares were in progress at the time of the 21 cm measurements.

Wadsworth Flare Spectra. A first survey of the spectra of flares obtained with the Wadsworth spectrograph indicates that for most flares, even flares of high importance, the $H\alpha$ emission line does not exhibit the great width usually attributed to it in the existing literature. In a very small number of cases $H\alpha$, and the other Balmer lines, are very broad and bright. The spectrum of one such flare (1958, July $30^d15^h32^m$, S14 W67, Imp. 2) has been examined in great detail. More than 100 lines were affected by the flare. One-fourth of these lines, including $H\alpha$ to H_{14}, and 4686 of *He*II and four *He*I lines, are in obvious emission brighter than the neighboring continuum. For another fourth, the flare caused only an apparent diminution of absorption. For half of the lines affected by the flare, the characteristic spectrum is a narrow emission component superimposed on a broad absorption line. Several of the iron multiplets are completely represented in the flare spectrum.

Evaluation of Flares Observed During the IGY. The numerous, world-wide, and often differing, reports of flares observed during the IGY have been evaluated and brought together into a single-entry, chronological list of flares for thirteen of the eighteen months of the IGY. This work will be continued for the entire IGY, and when completed, the data will form the basis for the analysis of flares and associated terrestrial effects during the IGY.

Doppler Motions in Fraunhofer Lines. A long investigation concerned with the measurement of isophotometer tracings of Fraunhofer lines has been completed by Mohler, Goldberg and Unno and is being prepared for publication. The latter phases of the work have been carried out at the University of Tokyo by Unno with the assistance of Mr. Ichimura. Results on local Doppler shifts at various points along the solar radius have been obtained for five metallic lines of intermediate strength as well as for $H\alpha$, $H\beta$ and the D_1 line of Na.

ROBERT R. MCMATH, *Director*

National Bureau of Standards, Washington, D. C., and Boulder, Colorado.

Traditionally three general programs at the National Bureau of Standards have contributed independently to astrophysical research: (a) fundamental work on wave length standards and spectrum analysis, observations of line intensities, and the critical compilation of atomic energy levels; (b) the development of accurate thermal standards for laboratory gases and for radiometric studies of astronomical objects; (c) since the creation of the Central Radio Propagation Laboratory, an investigation of the fields of solar physics and solar-terrestrial relations, and continuous absorption coefficients.

In recent years the interrelation among these fields of activity has developed conspicuously. Modern trends in astrophysics and in other fields dealing with hot gases have emphasized the urgent need for the systematic accumulation of accurate data and for a detailed physical approach. Consequently, an attempt is being made to broaden the scope of work related to astrophysics. In view of present needs, the strengthening and coordination of a unified interdivisional and interlaboratory program on "Measurement and Standards in Plasma and Astrophysics" will be a major focus of activity within this Bureau. The general program separates naturally into three parts, all of which will be carried on simultaneously.

A. *Atomic properties*: A comprehensive program to provide energy levels; dissociation, ionization, and activation energies; interaction cross sections, both optical and collisional; and transition probabilities, including "forbidden" lines.

B. *Gases in a quasi-steady, and not necessarily thermodynamic equilibrium state*: A study of spectroscopic and radio-frequency diagnostic methods; of collective atomic parameters such as line shapes, shifts, and widths, which depend upon the interaction of groups of atoms; a study of the statistically-steady state of an ensemble departing from the condition of local thermodynamic equilibrium; investigation of the possibilities of establishing standardized analytical techniques for describing such gaseous configurations.

C. *Study of non-static gases*: The study of the properties of plasmas, with particular attention to the coupling between their electromagnetic properties and dynamical state, including application of parts A and B to astrophysics.

A systematic program on certain phases of A above has been in progress for many years at the Washington Laboratories of the Bureau. The current report of activities may be summarized as follows:

Laboratory Spectra. The program on "Atomic Energy Levels" has formed the backbone of this activity. Three volumes have thus far been published. The fourth, which will deal with rare-earth spectra, is in its initial stage of preparation.

During the past year the spectra of hafnium have been reobserved and greatly extended by using as a source microwave-excited quartz tubes containing a milligram of hafnium halide. Similar excitation sources containing ytterbium metal have been used successfully to extend the observations of ytterbium spectra, and promise to be a boon to all future research in atomic and molecular spectra. They are particularly promising in the case of rare-earth spectra, most of which are very incompletely known.

A description and analysis of the first spectrum of iodine (I I) has been published [1]. A homogeneous line list of Th I containing some 15,000 lines and including Zeeman observations, has been extended to the far infrared region. A total of 150 new energy levels has been discovered, and further work on the analysis is in progress [2]. This work has been aided greatly by theoretical predictions of the positions of energy levels from low, even configurations. These studies include also the spectra Re I Re II, Ru I, and Hf I [3].

The He I line at 5017Å has been precisely observed interferometrically with the resulting wave length equal to 5017.0772 ± 0.0003Å (vac) [4]. This is of special importance in reevaluating data used to determine the best value of the Rydberg constant. Incidental to this work a monograph on He I is nearing completion.

Work has continued on the tables giving the relative intensities of lines of 70 elements observed under standard conditions. A new calibration of the copper arc reference standard has been used for some 10,000 lines in the range 2400Å to 3300Å, to improve the accuracy of the intensities.

A new table of wave numbers (1000 pages, in 2 volumes) is in press [5]. It gives with high accuracy the index of refraction of the atmosphere, and the number of waves per centimeter in vacuum, of any wave length from 2000.0000Å to 1 millimeter, measured in air.

Some ten years ago, a program on atomic cross-sections—photon and electron—was initiated. The best known aspect of this work was the observational determination of the H^- and O^- absorption coefficients. This work has continued along the lines of studying the negative ions of atomic hydrogen [6], oxygen [7], and molecular oxygen [8], and a survey of astrophysical applications of these data [9]. Radiative attachment coefficients have been computed from the absorption data. Ionization cross-sections for atomic hydrogen have been calculated for energies near threshold [10]. A calculation of the inelastic scattering of electrons from H^- has been completed [11].

Astrophysics. Analysis of the data on the spectrum of Jupiter obtained from observations made in 1957 at the Slope Observatory on Mauna Loa, Hawaii, has been completed [12]. The results include the first detailed measurements of the structure of the NH_3 and CH_4 bands in the red region of the spectrum, and verify the presence of H_2, and of a more complex molecule, probably N_2O_4, in Jupiter's atmosphere.

Work has continued on the preparation of a current edition of solar spectrum wave lengths. The data collected for the program on "Atomic Energy Levels" are being used to revise and extend the identifications and excitation potentials of atomic lines. Molecular identifications are also being revised, as illustrated by current papers on CH and OH [13]. Minnaert and his staff have completed the measurements of solar equivalent widths from 8700Å to the short-wave limit 3400Å, for inclusion in this edition.

Plans are being formulated for a revision of the 1945 Multiplet Table.

In anticipation of future astrophysical needs in the vacuum region, a major task will be further descriptions and analyses of important spectra in the region short of 2000Å. Here increased precision of laboratory wave lengths, the extension of series in high-ionization spectra of abundant elements, the study of stripped atoms, and general improvement of the accuracy of spectroscopic ionization potentials are among the most urgent requirements of the extensive program in astrophysics now being launched at this Bureau.

The astrophysical aspects of "B" and "C" have been carried on mainly at the Boulder Laboratories, and expansion of efforts in these directions will be, for the most part, continued there. An extensive program has been conducted on the structure of the solar atmosphere, and the physical processes associated with the transfer of radiation in a gas departing from conditions of thermodynamic equilibrium. This work includes the following studies: the radiative source-function [14], departures from ionization equilibrium [15], the use of the strong Balmer lines for atmospheric analysis [16], these phenomena in novae and gaseous nebulae [17], joint problems in aerodynamics and astrophysics [18], and solar flares [19]. Much of this work has been done in active collaboration with the High Altitude and Sacramento Peak Observatories.

At the Boulder Laboratories research in related fields has continued. Roach and his colleagues have carried on extensive investigations of the airglow, aurora and zodiacal light [20, 21].

It is hoped that future reports will reflect the efforts of the Washington and Boulder Laboratories, acting in close liaison, to continue basic research of astrophysical importance on the larger scale outlined above.

In conclusion, it should be stated that the present report is the result of extensive collaboration. Cordial thanks are due R. N. Thomas, L. M. Branscomb and the members of the Spectroscopy Section.

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CHARLOTTE E. MOORE,
Atomic and Radiation Physics Division

Perkins Observatory, The Ohio State University and Ohio Wesleyan University, Delaware, Ohio.

Personnel. Dr. Geoffrey Keller, who has been on leave of absence for two years while serving as Program Director for Astronomy of the National Science Foundation, resigned as Director of the Observatory in April, 1959. Dr. J. E. Merrill resigned from the Department of Astronomy at Ohio Wesleyan at the end of the 1958–59 academic year. Professor Philip Stanger has been named to act in his place during the coming year. Dr. J. A. Hynek continued on leave to the Astrophysical Observatory of the Smithsonian Institution at Cambridge.

Dr. Arne Slettebak was promoted to Associate Professor and Dr. Walter Mitchell to Assistant Professor. The other faculty members of the staff are Professors Bobrovnikoff and Keenan.

The annual McMillin Lecture was given by Dr. Donald Osterbrock of the University of Wisconsin.

Two graduate students, Mr. Leonard Maestre and Mr. Jack Wright, received the degree of Master of Science from the Ohio State University.

Instrumentation. Mr. Michael Schottland of Martinsville, Virginia completed his gift to Ohio Wesleyan University of a 32-inch reflecting telescope and a 16/24-inch Schmidt camera, together with auxiliary cameras and finders. These instruments, which were made by the J. W. Fecker Co., have been shipped to the Perkins Observatory, where they will be mounted.

Construction of the Yoder grating spectrograph for the 69-inch reflector occupied a major part of the time of the machine shop. Most of the coming year will be needed for completion of the mechanical parts and testing of the optics in place.

RESEARCH

Early-Type Stars. A joint program for the discovery of metallic-line and peculiar A-type stars was completed by A. Slettebak and J. J. Nassau of the Warner and Swasey Observatory. A catalog of 48 metallic-line stars and 15 *Mn*, *Si* or *Cr* stars was published (*Ap. J.* **129**, 88, 1959).

One of the faint O-type stars (GS-259-8) found in the 1957 Hamburg objective-prism survey by Slettebak and Stock was investigated by G. Münch on Palomar Observatory coudé spectrograms. It proves to be a subdwarf which may be a member of the Lacerta aggregate (*Ap. J.* **129**, 852, 1959).

Spectra of Binary Stars. The observations by Slettebak of spectra of both components of visual binaries have been extended to 260 components, with only about 20 systems needed to complete the survey. Spectral classification and estimation of axial rotation will be undertaken during the coming year.

On spectrograms of the blended B and C components of the triple system γ And, Slettebak noticed two sets of lines. It appears likely that component B is the spectroscopic binary, with both stars close to Ao in type. Velocity curves and orbital elements were determined by Maestre and Wright.

A number of spectrograms of such combination variables as Z And and AG Peg have been taken by Mitchell.

Mira Variables. With the aid of a grant from ONR, Keenan spent the period October, 1958 to March, 1959 as a guest investigator at the Mount Wilson and Palomar Observatories. Coudé spectrograms of the yellow region of 16 Mira variables were taken near maximum light with the 100-inch reflector. Interstellar D-lines of sodium were observed in 6 of these stars. For X Mon it was possible to estimate the luminosity as $M_v = -0.7$, from a comparison with the interstellar lines in 4 nearby stars of early type.

Revised spectral types have now been determined for 44 Mira variables in the range K4e to M6e.

Radial Velocities. For 7 stars of types Ko to Mo, radial velocities were measured by Wright as a test of the usefulness of grating spectrograms of moderate scale (50 Å/mm) in the visual region. It was found that the internal probable errors

could be held to less than 2 km/sec for the means of pairs of plates.

Solar Physics. Mitchell extended the analysis of the center-limb variation of 14 selected absorption lines, which he had measured while at the University of Michigan. After reducing the electron pressure by a factor of two over older models in the region of line formation, he was able to carry out integrations in monochromatic optical depth near 8000, 11,000 and 16,000 Å, obtaining consistent atmospheres (*Ap. J.* **129**, 369, 1959). This implies that the present theoretical values for the free-free contribution to absorption by negative hydrogen ions (Chandrasekhar and Breen) are not significantly in error. In connection with this work, extended tables of the H^- absorption coefficient were prepared for publication.

Mitchell has begun a cooperative program with Dr. O. Mohler of the University of Michigan Observatory for the preparation of a photometric atlas of the solar spectrum from 3000 Å to 3650 Å. Observations were begun with the Michigan solar spectrograph on Mount Wilson in July, 1959.

Atmospheric Scintillation. The contract with the Air Force Cambridge Research Center for the optical investigation of density fluctuations in the earth's atmosphere terminated in June, 1959. During the last year the dual 1-inch telescopes with variable separation, and the automatic analog computer, were used by Mr. Philip Barnhart and the project staff to measure sizes and motions of the elements of the shadow pattern. The pattern motions were compared with balloon observations of wind velocities in the upper atmosphere (supplied by the Sulphur Grove Weather Station) on 9 nights. The optical data provided unique determinations of the altitudes of strong winds, usually between 40,000 and 50,000 feet, on 7 nights. The autocorrelation method of Keller could be used to measure dimensions of density fluctuations in the range from 3 to 20 inches. On the 9 nights the measured element diameters all lay between 6.5 and 11 inches.

Shock Tube Laboratory. Under the sponsorship of the Air Force Cambridge Resarch Center construction of a shock tube was begun late in 1958. The shock tube laboratory will be located in the McMillin Observatory at The Ohio State University. The purpose is to study spectroscopically the luminosity excited by shock waves under conditions which for short periods of time will simulate stellar atmospheres. The project is under the direction of Slettebak, and Dr. Lawrence Aller of the University of Michigan is a consultant. K. N. Rao helped design the tube, which has an expansion section twelve feet long and two inches in diameter.

Auroral Survey. The automatic camera that photographs the sky on every clear night has been kept in operation throughout the year by Mr. Charles Smale. A number of aurorae extending to our latitude have been photographed on this project, which is carried out in cooperation with Cornell University under the supervision of Mitchell.

Moon and Planets. At the request of Wright Air Development Center, reports giving bibliographies and summaries of the known physical conditions have been prepared for the Moon by Bobrovnikoff, for Venus by J. H. Shaw and Bobrovnikoff, and for Mars by Shaw.

Instruction. A rapid increase in undergraduate interest in astronomy courses at Ohio State has taken place in the last few years. Bobrovnikoff has assumed primary responsibility for the teaching program. Total enrollment was above 290, including a course in geodetic astronomy given by Mitchell and Professor Alwyn Robbins in conjunction with the Institute of Geodesy.

PHILIP C. KEENAN, *Acting Director*

Princeton University Observatory, Princeton, N. J.

R. Danielson joined the Flying Telescope Project as a Research Associate on the Observatory Staff. F. D. Kahn was a Visiting Fellow for three months during the spring as a Peyton Fellow.

RESEARCH PROGRAM

Stellar Interiors. Schwarzschild and Härm have investigated the physical conditions in a red giant at that evolution phase at which the model sequence derived the previous year with the Princeton Electronic Computer terminated. They found that in this phase the helium burning, though still very weak, replaces the hydrogen burning already as the critical process which determines the rate of evolution. Since subsequent to this phase the helium burning may cause a runaway of the central temperature, the time step used in the numerical calculation has to be chosen successively smaller and smaller until

a new more stable configuration is reached. Accordingly the problem has been recoded, this time for an IBM 650, and a new evolutionary model sequence, starting where the preceding sequence left off, has been begun.

Morton has investigated the mass loss by the more massive component of a binary at the time when this component in its evolutionary expansion reaches the zero velocity surface. He found that such a star will lose a substantial fraction of its mass in a short time if it contained at the critical moment already a substantial inhomogeneity in composition.

Weymann has studied certain facets of the problem of mass ejection from red giants and has shown that a star like α Herculis—barring some very special circumstances—must eject mass at an effective rate if it possesses a corona with a temperature higher than 200,000°.

Solar Atmosphere. Schwarzschild has completed the correlational analysis based on the best granulation photographs obtained in the 1957 balloon flights. This analysis shows that the intensity correlation function for the solar granulation drops to one half of its maximum value at a correlation distance of about 375 kms. and that the root mean square temperature fluctuation in the solar photosphere is larger than $\pm 60°$ but probably smaller than $\pm 100°$.

Rogerson has analyzed a photograph of the solar limb taken by the balloon-borne telescope in 1957. This work extends the true center-limb intensity profile to within two seconds of arc of the limb for radiation with a mean wavelength of 5400 Å; the previous data extended only to about 12 seconds of arc.

Stellar System. Van Wijk has continued his analyses of stellar velocity distributions, based on the assumption that at the time of origin the velocity distribution in each region of the Galaxy was Maxwellian, with mixing then occurring. Computations on an IBM 650 and interpretation of the observed Bottlinger diagram lead to the tentative conclusion that the velocity of escape from the Galaxy in the solar neighbourhood should be considerably increased above the previously accepted value.

Field has attempted to explain the very wide emission lines in nuclear-emission galaxies by invoking non-coherent electron scattering by the ionized gases in the nuclei. It was shown that the transfer equation of Münch is much simplified by assuming spherical symmetry. The calculated line profiles bear some resemblence to the observed ones, but the optical depths appear to be several times too small, judging from electron densities deduced from line intensities.

Radio Astronomy. A measurement of atmospheric extinction at 21 cm wave length was carried out by Field using the facilities of the National Radio Astronomy Observatory. The data are now being reduced.

The high-frequency radio spectrum of Jupiter was considered theoretically by Field. The emission, which attains blackbody temperatures up to 40,000°K, was shown not to originate in Jupiter's atmosphere or ionosphere. It appears likely that gyro-radiation by electrons in Jupiter's magnetic field is responsible. Cosmic ray electrons do not appear to carry enough energy, while solar particles could easily supply the required amount. The question as to whether only cyclotron frequency, or various harmonics of it (because of high electron energies), are involved cannot be settled definitely from the present data.

The possibility that the low-frequency signals from Jupiter may be caused by electrical discharges has been considered by Zabriskie. A separation of electric charges by precipitation, resulting in discharges, would be consistent with the limited evidence, and the energies involved can account for the observed energies in the radio bursts.

Interstellar Matter. Rogerson, Spitzer, and Bahng have installed and put into operation a pulse-counting photoelectric photometer in the coudé spectrograph of the 100-inch Mount Wilson telescope. Spitzer and Rogerson have used the equipment for measurement of equivalent widths of interstellar absorption lines. A search was made, with negative results, for interstellar *Al* I at 3944.0 Å in the spectrum of ζ Per. Equivalent widths of interstellar CH^+ at 4232.6 Å were measured in the spectra of nine stars. These measures indicate no unique relationship between the strength of this molecular line and color excess except that unreddened stars show no line. The interstellar sodium D-lines were measured in nine stars. These equivalent widths agree with earlier Mt. Wilson measurements to within two per cent.

Flying Telescope Project. The twelve-inch solar telescope has been modified to permit ground control of focussing and pointing, and also to reduce the vibration level. The equip-

ment modification and construction has been completed by RCA, Perkin-Elmer Corporation, Data Controls Inc. and L. C. Eichner Instruments. Bahng and Danielson have acted as coordinators of this work and have assembled the complete instrument in preparation for the planned flights in the summer of 1959.

The Perkin-Elmer Corporation has completed the design study for the 36-inch balloon telescope, in frequent consultation with Schwarzschild, and has been given a contract for the actual design and construction of this telescope. The Corning Glass Works are in the process of producing the necessary fused silica blanks for this instrument. The entire balloon program is as before being supported jointly by the National Science Foundation and the Office of Naval Research.

The problems of a satellite ultra-violet telescope have been analyzed by Spitzer and Zabriskie. Present plans call for a mirror of 24-inch aperture, with a conventional ultra-violet spectrograph placed at the Cassegrain focus, and designed to measure photoelectrically the spectrum intensity of a star in the range from 800 to 3200 Å. A conceptual design of the equipment needed for setting, guiding, temperature control, data storage, etc., has been carried out. Proposals for a design study have been solicited from a number of firms, and it is expected that a contract will be negotiated shortly.

LYMAN SPITZER, JR., *Director*

Observatory of Rensselaer Polytechnic Institute, Troy, New York.

This report covers the interval July 1, 1957 to August 31, 1959.

Personnel Changes. Dr. Pearl R. Lichtenstein joined the staff as a research associate (part time) in September 1957. Mr. Masakazu Oshima became a research assistant in November 1958. Mr. Raymond E. Falconer became a research assistant in January 1959. Dr. Vincent J. Schaefer joined the staff as Adjunct Professor of Meteorology, effective in September 1959. Dr. Fleischer's title has been changed to Professor of Astronomy, and Dr. Meltzer's title to Assistant Professor of Astronomy. At the request of the Board of Trustees of Dudley Observatory, the cooperative arrangement described in previous reports between Dudley Observatory and Rensselaer Polytechnic Institute came to an end in December 1957.

Mr. William E. Meyer was a graduate assistant from July 1957 to June 1958. Mr. Robert W. Redlich's appointment as graduate assistant ended in June 1958. Mr. Peter B. McCorison's appointment as student technician ended in June 1959 upon his graduation. Mr. William R. Adair has served as student assistant since September 1957. Mr. John W. Loofbourrow served as student assistant from September 1958 to June 1959. Student assistants in the summer of 1958 were Mr. Charles Hathorn and Mr. Jerry Weinberg, and in the summer of 1959 Mr. Edward Dirkswager, Jr., Mr. William Hy Mak, and Mr. Terry Roark. Mrs. Nicole Belasky resigned as secretary in May 1958, and has been succeeded by Mrs. Cassie Young.

Instrumentation. The apparatus for detecting sudden cosmic-noise absorptions at 18 megacycles has been functioning with minor modifications since its inception in February 1957. An improved receiver has been designed by Watters and McCorison, and is partially completed. An improved antenna system for this project will be erected.

A new receiver for the detection of sudden enhancements of atmospherics at 27 kilocycles was designed and constructed by Haskell.

The 517-megacycle solar patrol electronics constructed by Pike was operated for about one-third of the International Geophysical Year; a receiver of improved sensitivity and stability is now under construction by him.

A breadboard model of the 517-megacycle interferometer electronics was constructed by Redlich, and was described in a paper by him and Fleischer to the Washington meeting of URSI in April 1958. The final version of the interferometer electronics has been constructed by Oshima. He has also designed Yagi antennas which will be mounted equatorially. A site 800 feet northeast of the laboratory building has been cleared for the interferometer.

Because of suspected relations between the received 18-megacycle cosmic noise intensity and certain meteorological parameters, a radioactive point for measuring atmospheric potential gradient, loaned by the Munitalp Foundation, and a microbarovariograph, loaned by the Lamont Geological Observatory, have been installed. In addition, normal temperature and rainfall measuring equipment is being operated as a "cooperative observer" for the U. S. Weather Bureau. A photoelectric aurora recorder has been

designed by Mr. William Hooper as a master's thesis under Meltzer.

The microwave apparatus for experimental determination of scattering coefficients has been considerably improved, and it is now possible to measure not only side scattering, but also total cross-sections, to an accuracy of better than five per cent for arbitrarily shaped particles.

A Gaertner measuring engine with a 12-inch screw, suitable for positional astronomy measurements, has been acquired by Rensselaer.

Research. Interstellar Material. Preliminary results from the microwave scattering apparatus have been obtained for certain non-spherical particles. They indicate the possibility of a difference in wave length dependence of interstellar extinction parallel and perpendicular to the magnetic fields in spiral arms. A wide variety of laboratory experiments and astronomical observations is opened by these investigations. This work was described in a paper by Greenberg and Pedersen to the Fifth Conference of the International Commission for Optics in Stockholm in August, and was the subject of discussion by Greenberg at several observatories in Western Europe.

A survey of the Palomar Sky Atlas for small isolated dark nebulae was completed by Mr. Richard Blake as a senior thesis under Fleischer. It is intended that these objects will be investigated for hydrogen content with the equipment of the National Radio Astronomy Observatory.

Solar-terrestrial Relations. A continuous record is being made of received cosmic-noise intensity at 18 megacycles, and intermittent records have been secured of sudden enhancements of atmospherics at 27 kilocycles and of intensities of solar emission at 500 megacycles. A continuous patrol of intensity of aurora light will be made in the future. Records are being accumulated of micro-pressure fluctuations in the atmosphere and of the changes in atmospheric potential gradient. Many of the events recorded have been reported through the usual International Geophysical Year channels. In addition, complete reproductions of the 18-megacycle strip charts are now being published, usually each month. This has the advantage that minor events are made available to other workers in the field without detailed tabulation.

An analytical program is under way, with the objective of explaining the long-term and the sudden variations in the received 18-megacycle noise, both with respect to the physical conditions in the ionosphere and with respect to the relation between sudden events and solar activity. Pearl Lichtenstein and Falconer are engaged in this work. Mrs. Lichtenstein has considered the effects of pulses of ionizing radiation on the absorptive properties of the ionospheric D-layer, and has been able to reproduce observed SCNA curves on the basis of a simple model. She reported this work to the Toronto meeting of the American Astronomical Society. Falconer has been engaged in the reduction of the large volume of data to a standard daily curve, and in correlation of 18-megacycle events with other solar and terrestrial events. There are a number of instances of apparent relation between atmospheric potential gradient and small variations in received 18-megacycle cosmic noise, and at least one indication of an apparent pressure oscillation accompanying a Type V solar burst. The data are being handled in part with the aid of Rensselaer's IBM 650 computer.

Solar Spectroscopy. Meltzer has completed an investigation in cooperation with Barbara Bell of Harvard College Observatory concerning the Doppler widths of solar absorption lines. This investigation was presented to the American Astronomical Society at the Madison meeting and published as indicated below.

Upper Atmosphere and Meteorology. An interest in atmospheric physics has been growing in our group, in part as an extension of the solar-terrestrial relations described above, in part because of certain common aspects of the physics of the atmosphere and of the interstellar medium, and in part as a response to the growing interest in engineering circles in the environment of space, which includes both the atmosphere and interplanetary regions. Work along this line has included a series of measurements of 20- and 40-megacycle artificial-satellite transmissions, as well as the study of meteorological relations with the 18-megacycle records. A program of basic studies of condensation mechanisms in the atmosphere is being planned by Schaefer. A study of certain electrical properties of the atmosphere has been proposed by Falconer.

Publications. Of the new series *Rensselaer Observatory Publications*, numbers 1–7, 9, and 10 consisted of reports of 18-megacycle cosmic-noise intensities, by Fleischer and Lichtenstein. ROP 8 contained a paper "Doppler Widths of Solar Absorption Lines," by Barbara Bell and Alan Meltzer, reprinted from the *Smithsonian Contributions to Astrophysics.*

Other publications appearing since the last report, all by Fleischer, were:

"Parallax and Orbital Motion of the Triple System Wolf 630-629 from Photographs Taken with the 24-inch Sproul Refractor," *Astronomical Journal* **62**, 379, 1957.

"Auroral Absorption of 18-megacycle Cosmic Radio Waves on February 11, 1958," *Nature* **181**, 1156, 1958.

"Variations in 18-megacycle Solar and Cosmic Noise, *Proceedings of the Paris Symposium on Radio Astronomy*, Ronald N. Bracewell, Editor, Stanford University Press, 1959, page 208.

Education. We have given some thought to the function of a master's degree in astronomy, analogous to the master's degree common in physics, especially as related to the expanding industrial opportunities for astronomers at the present time. It is felt appropriate that a college of the character of Rensselaer should attempt to fill this educational need. New courses pertinent to this end have been introduced. Their content includes celestial mechanics, stellar atmospheres, solar phenomena, and the interplanetary and interstellar medium, all taught from the astronomical point of view. There are available also courses in stellar astronomy which are appropriate for more advanced work. It is hoped that a number of the students who embark on this program will be motivated to continue toward the doctorate. We expect that thesis work, particularly for doctoral students, will be done at the national radio and optical observatories, in addition to making use of our own laboratory and observational equipment.

Other Activities. One or more staff members have attended each of the recent meetings of the American Astronomical Society and the meetings of URSI, the American Geophysical Union, and the American Meteorological Society in Washington in May of this year. Meltzer took part in the Institute on Dynamical Astronomy held at Yale University this summer. Fleischer attended the General Assembly of URSI in Boulder in August 1957, the dedication of the National Radio Astronomy Observatory in October of that year, the Paris Symposium on Radio Astronomy and the Moscow General Assembly of the IAU in 1958. He is a member of the committee on frequency allocation of the U. S. National Committee of URSI, and is chairman of the Scientific Advisory Committee to the Whiteface Mountain Authority of the State of New York.

The Troy Astronomy Club and the Rensselaer Astrophysical Society continue to make extensive use of the Campus Station of the Observatory. Numerous public lectures on astronomy have been given by Fleischer and Meltzer.

Gifts and Grants. Our work during the report interval has been supported by a number of sources, among whom we would particularly like to mention the American Oil Company, Mr. Roland Bourne, the Trustees of the Dudley Observatory, the Benjamin Apthorp Gould Fund, the U. S. National Committee for the International Geophysical Year, the National Science Foundation, the Office of Naval Research, the Rensselaer Research Grants Committee, Research Corporation, the Rockefeller Foundation, the Society of the Sigma Xi, and Mr. E. Weil.

Visitors. During the report interval, visitors and lecturers included F. M. Bateson, Marshall Cohen, John Cox, Leo Goldberg, Frank Kerr, Julius London, T. K. Menon, Paul W. Merrill, Joseph Pawsey, Olaf Rydbeck, Charles Seeger, Harlow Shapley, Harlan Smith, Jaako Tuominen, and Gart Westerhout.

ROBERT FLEISCHER, *in charge*

Department of Physics and Astronomy, University of Rochester, Rochester, New York.

Personnel: Mr. G. Pinski and M. Miller served as research assistants. Mr. R. A. Santirocco completed Ph.D. degree requirements at the University of Rochester, his thesis topic being a curve of growth analysis of RR Lyrae and other F Stars.

Stellar Interiors: Mass-10 star models were studied further during the year by M. Savedoff with the assistance of Miss S. Zalitacz and S. Van Dyck. An evolutionary series of models was obtained. It was found that the assumption of semi-convection leads to an inconsistency in that the hydrogen content in part of the semi-convective zone increases with time. We tentatively attribute this increase to the effects of energy production in the semi-convective shell. The increase is physically possible as long as it implies a net inward flow of hydrogen, but the calculated models require an appreciable outward flow. This difficulty may be present in other semi-convective zone models.

Since serious doubts exist as to the physical

validity of these models, no perturbation analysis were undertaken.

Gamma Ray Astronomy: The results of an estimate of γ ray fluxes was published by M. Savedoff in *Nuova Cimento*. Experimental equipment for observation of photons with $E > 10$ Mev is being developed in our cosmic ray group by Drs. M. Kaplon, E. Hafner, G. Fazio and J. Klarmann in anticipation of balloon flights during the summer 1959.

Radio Astronomy: Collaboration with the Department of Terrestrial Magnetism, Carnegie Institution of Washington on research in radio astronomy is now under way. Previous data by H. L. Helfer and W. Erickson of high latitude hydrogen has been analyzed by H. L. Helfer in terms of Taylor expansion of the local velocity field. The symmetric part of the velocity gradient tensor appears to be represented by its principal axes

$$\lambda_1 = +1.1 \pm 0.1 \quad \lambda_2 = +0.8 \pm 0.1 \quad \lambda_3 = -1.1 \pm 0.1$$
$$l_1^I = 92° \mp 7° \quad l_2^I = 75° \mp 5° \quad l_3^I = 172° \mp 2°$$
$$b_1^I = 55° \mp 17° \quad b_3^I = 33° \mp 17° \quad b_3^I = +6° \pm 1°$$

where the diagonal elements λ are on an as yet undefined scale. This work was reported at the AAS meeting and will be submitted for publication shortly. Additional data were gathered at DTM during the year.

H. L. Helfer and M. Savedoff obtained data on hydrogen line emission at high galactic latitudes. A continuing study is required to unambiguously establish the reality of signals $<2°$K amplitude with half widths ~ 50 km/sec.

Stellar Abundances: During the year H. L. Helfer completed some projects undertaken while at Mt. Wilson and Palomar Observatories in collaboration with J. Greenstein and G. Wallerstein. The results appear in *Ap. J.* **129**, 700, 1959, and *Ap. J.* **129**, 720 1959. Work along these lines is continuing.

Instrumentation: The Institute of Optics is now undertaking development of novel astronomical instruments for Sacramento Peak Observatory and for NASA principally under the guidance of Harold Stewart with the advice of members of our department.

R. E. MARSHAK, *Chairman*

Sproul Observatory, Swarthmore College, Swarthmore, Pa.

It is our sad duty to record the passing on January 30 of Vera M. Dargie, secretary for the departments of Mathematics and Astronomy since 1945. A loyal staff member of the Observatory, she also contributed her secretarial services to the Swarthmore College Orchestra and the William J. Cooper Foundation.

Mr. Wyller gave the year course in Descriptive Astronomy and a seminar in Observational Astrophysics. Mr. van de Kamp was on leave during the first semester of which he spent two months at the observatory in Utrecht while lecturing in the Netherlands. Mr. van de Kamp, Mr. Wyller and Miss Lippincott attended the Tenth General Assembly of the International Astronomical Union in Moscow; Mr. van de Kamp was appointed president of Committee 26 (Double Stars). Mr. van de Kamp attended meetings of AURA, Inc., in December at Ann Arbor and in March at Tucson.

Mrs. Dorothy Allen was appointed assistant in astronomy and, with Mrs. Mary Jackson, assisted with the measuring and reduction of photographic plates. William Poole, Jr., John R. Merrill, Frank W. Pooley, H. John Wood and F. Jerrold Josties took part in the night work. Robert H. Koch and Sheila Brown Bishop were research assistants during the summer of 1958.

Mr. J. J. Raimond, Jr., Director of the Planetarium, The Hague, Netherlands, was visiting professor during April and May and gave a short course on the structure of the Milky Way System. Visitors to the Observatory included Arthur Beer, Paul W. Merrill, and Harley Wood.

On June 11, Laurence W. Fredrick received the Degree of Doctor of Philosophy from the University of Pennsylvania on the dissertation: The System of VV Cephei. He left the Observatory on June 15 to join the staff of the Lowell Observatory.

Photographic observations with the 24-inch refractor were made on 122 nights; a total of 1405 plates were taken. Evening observations were made on 105 nights, morning observations on 61 nights; 45 nights included both evening and morning observations.

PETER VAN DE KAMP, *Director*

United States Coast and Geodetic Survey, Washington, D. C.

Variation of Latitude. The latitude observatories at Ukiah, California and Gaithersburg, Maryland were continued in operation throughout the year, July 1, 1958 to June 30, 1959. These observatories, located on parallel 39° 08′,

participate in the International Latitude Service Program for the study of polar motion. Leonard F. Caouette was the observer at Ukiah; Alfred W. Helm was the observer at Gaithersburg, assisted since January, 1959 by John D. Mulchi. At Ukiah, 4,139 star pairs were observed on 257 nights, complete sets being observed on 182 nights. At Gaithersburg, 3,737 star pairs were observed on 280 nights, with complete sets on 104 nights.

Longitude and Latitude. In conjunction with the Longitude and Latitude Program of the IGY, the special observatory at Honolulu, T. H. was continued in operation throughout the year. The observatory was under direction of LCDR Eugene A. Taylor, assisted by LT Howard A. Garcia, prior to January, 1959 at which time LT Garcia assumed direction. A continuous program was maintained for observations with the Markowitz dual-rate moon camera and the Danjon astrolabe with impersonal micrometer. Time control was obtained from a quartz clock monitored by signals from WWVH, Maui, T.H. The astrolabe observations were recorded on a digital printing chronograph. A total of 206 sets of moon camera plates and 413 sets of astrolabe observations were obtained during the year ending June 30, 1959.

Geodetic Astronomy. Astronomic position observations were extended westward along the 35th parallel geoid profile from Texas to California, consisting of 10 first-order and 53 second-order determinations. A total of 21 astronomic positions and 20 azimuths were observed in connection with triangulation control and various special geodetic projects.

CHARLES PIERCE, *Assistant Director*

U. S. Naval Observatory, Washington, D. C.

Captain Carl G. Christie, U. S. Navy, served as Superintendent until 30 June 1959, when he was relieved by Captain Byron L. Gurnette, U. S. Navy. Commander William M. Robinson, U. S. Navy, continued as Deputy Superintendent.

K. Aa. Strand was appointed Director of the Division of Astrometry and Astrophysics on 1 August 1958. Organizational title changes of 17 June 1959 in the Nautical Almanac Office were: R. L. Duncombe, Assistant Director for Research, and R. F. Haupt, Assistant Director for Production. Other appointments to the staff were: O. G. Franz and Carroll A. Lidback as astronomers, and Charles K. Capps as mathematical aid. W. A. Geegh, J. A. Hughes, Miss Anne C. Pyne, A. R. Upgren, Jr., and P. A. Wehinger received temporary appointments for the summer of 1959. Resignations from the staff were John S. Hall on 5 September 1958 and Miss Susanne Ellis on 3 November 1958.

D. H. Sadler of H. M. Nautical Almanac Office visited the Observatory and consulted with members of the Nautical Almanac Office during September 1958. H. S. Spigl of the Perth Observatory, during February and March, H. J. M. Abraham of the Mt. Stromlo Observatory, during April, and A. Williams of the Yerkes Observatory, during May and June, 1959, were guest astronomers at the Observatory.

Other scientists from abroad who visited the Observatory were: J. Abdala, U. Adelsberger, J. P. Blaser, P. Bourgeois, R. L. Corke, A. Danjon, L. Essen, K. Gottlieb, R. A. Hirvonan, S. N. Kalra, Mrs. A. Massevitch, A. A. Nemiro, J. J. Nissen, K. Ogorodnikov, F. Rutllant, S. Slaucitajs, R. H. Stoy, E. Tengstrom, H. W. Wood, and M. S. Zverev. Tours were held for 7919 public visitors to the Observatory during the year.

G. M. Clemence, Julena Duncombe, R. L. Duncombe, O. G. Franz, Simone Gossner, Wm. Markowitz, F. P. Scott, S. Sharpless, and K. Aa. Strand attended the Moscow meeting of the International Astronomical Union, August 1958. Wm. Markowitz attended, in August 1958, the C.S.A.G.I. (IGY) meeting held in Moscow and the International Radio Consultive Committee held in Geneva. G. M. Clemence, O. G. Franz, F. P. Scott, and K. Aa. Strand attended the Second Astrometric Conference held in Cincinnati in May 1959.

During the year 3,501 stars were observed on 236 nights with PZT No. 3 at Washington, and 4,483 stars on 285 nights with PZT No. 2 at Richmond, Florida.

Time signals emitted by quartz-crystal clocks at Naval Radio Stations at Annapolis, San Francisco, Canal Zone, and Guam were monitored. Time information was furnished the National Bureau of Standards for control of WWV. UT2 (Universal Time corrected for variation of longitude and for seasonal variation), was determined with the PZT's. E. T. (Ephemeris Time), determined with the dual-rate moon camera, was compared with the cesium standards of the Naval Research Laboratory, Washington, and the National Physical Laboratory at Tedd-

ington, England. A system of Atomic Time, called A.1, was established in cooperation with the Naval Research Laboratory.

Two hundred twenty-six sets of plates were taken with the moon camera on 132 nights. Plates have been received from Ottawa, Curacao, San Diego, Hawaii, and Sao Paulo. Reductions have been made of 738 plates.

Observations were made with the Danjon Impersonal Astrolabe on 66 nights.

An experimental dual-rate satellite telescope of 7 inches aperture and 40 inches focal length, designed by Wm. Markowitz, was constructed. Observations were made of Satellite 1958 Delta One, Sputnik III rocket, on 27 November 1958, and of Satellite 1958 Zeta, Atlas, on 13 January 1959 with this instrument.

The American Ephemeris and Nautical Almanac for 1960 was issued 5 January 1959. *The Nautical Almanac* for 1960 was issued 6 May 1959. The three parts of *The Air Almanac* for 1959 were issued 28 August and 5 December 1958, and 2 April 1959. *Astronomical Phenomena* for 1961 was issued 11 February 1959. The Nautical Almanac Office has undertaken the preparation of *The Ephemeris* for the Bureau of Land Management, Department of the Interior, beginning with the issue for 1960.

The Nautical Almanac Office has continued cooperation with numerous other government agencies, universities, and commercial laboratories concerned with atmospheric, geodetic, astronomical, and astronautical problems. An increasing demand for astronomical information and ephemerides has come from engineering organizations engaged in technological projects, often for data of a type not available because not previously needed for any purpose.

R. L. Duncombe's investigation of The Motion of Venus is in press and will appear shortly in *Astronomical Papers of the American Ephemeris* 16, Part 1. Research calculations concerning the orbits of artificial earth satellites, in connection with project Vanguard and project AESOP, were continued.

The theory of the motion of Mars is now complete, except for application of some numerical checks. The next step is to compare it with observations, for the purpose of studying the actual motion.

The calculation of the Laplace coefficients and their derivatives has continued as time on the computer permitted.

The AGK3R program, an international cooperative effort for determining the positions of 21,505 reference stars for the reduction of the AGK3 photographic plates, progressed very satisfactorily during the year. The meridian circle work is now 60 per cent completed and some of the participants expect to finish their commitments during the coming year. Over 104,000 observations were reported to the Naval Observatory during the year for the purpose of obtaining the apparent places required in the reduction of the observations. Approximately 219,000 apparent place reductions have been made for this program since it started in 1956. All but one of the thirteen transit circles committed to the program have commenced the observations of the reference stars.

Observations of the sun, moon, planets, and the four brightest minor planets were continued with the six-inch transit circle. The star list includes 7,544 AGK3R stars and 1,409 FK3 supplemental stars, as well as all of the FK3 stars north of $-31°$ declination. The total number of observations made with this instrument during the year was 12,860.

Observations of 11,326 AGK3R stars, 246 stars from Parenago's list, 17 Orion stars, and the four brightest minor planets were continued with the seven-inch transit circle. A total of 13,457 observations were made with this instrument during the year.

A list of about 3300 close double stars needing modern observations for the computation of proper motions was prepared by G. van Herk. The fainter stars will be observed photographically at the Leander McCormick Observatory and the remainder will be placed on the observing program of the seven-inch transit circle as the reference star work becomes completed.

J. E. Jackson has undertaken a discussion of the accumulated meridian circle observations of the minor planets, Ceres, Pallas, Juno, and Vesta.

A. N. Adams, with the assistance of J. L. Schombert, has continued his work on digitizing the micrometer readings of the transit circles. Attempts to use a simple synchro-system to drive a remote digitizer were abandoned because of troubles with a transmission lag which depended on the rate of turn of the right ascension micrometer screw. A more precise servo-repeater system is being designed.

The survey of the marginal zone of the moon

by C. B. Watts has been completed and the results are being prepared for publication.

The 15-inch astrographic telescope was completely overhauled and the 26-inch refractor was equipped with electro-mechanical controls during the year. A measuring machine, for plates up to 10 × 10 inches was completed in the Observatory Instrument Shop.

A major program of photographic observations of double stars was started with the 26-inch refractor. The program consists primarily of Struve stars with separations greater than 2".5. Special attention is being given to pairs for which continuous series of observations would lead to important improvements in their orbits, and to pairs having large parallaxes. Other pairs were included to obtain accurate relative positions, which compared with earlier or later positions of high accuracy would yield a check on the physical character of their motions. A total of 125 plates, each with approximately 60 images, were obtained during the year for this program. An additional 51 plates were obtained during February and March 1959 with the 24-inch refractor at the Lowell Observatory. The plates are measured with the Mann measuring machine equipped with a digitizer.

Miss E. Roemer continued the observations of comets for position, magnitude, and physical characteristics, with emphasis on objects too faint to be observed elsewhere. Comet Giacobini-Zinner was recovered on 8 May 1959, when it was of magnitude 20. Orbits were computed for Comets Burnham-Slaughter, 1958e, and Slaughter-Burnham, 1959a. Both were discovered at the Lowell Observatory. The latter comet is of special interest, having a period of 11.64 years.

J. L. Gossner continued the asteroid program with the 15-inch and obtained 31 plates. Observations over the past four years are now being reduced.

O. G. Franz investigated the proper motions of the h Persei cluster from plates taken with the 40-inch refractor at the Yerkes Observatory at an interval of 50 years. Preliminary results show evidence of a nearby cluster in the same region. Further photometric and spectrographic observations are required to confirm the presence of this cluster.

A. A. Hoag continued photometric work on galactic clusters in collaboration with astronomers at the Lowell Observatory. A total of 376 chart and multiple exposure plates were taken with the 40-inch reflector for this purpose. A series of IN plates were taken of the Orion Nebula Cluster in search of variables. A red sequence was established in that region using an infra-red photomultiplier, on loan from the Washburn Observatory.

Collaboration with the Carnegie Image Tube Committee was continued at the Flagstaff Station. M. A. Tuve, J. S. Hall, W. A. Baum, W. K. Ford, Jr., and T. E. Houck were guest investigators on this program, using the 40-inch reflector on 12 nights.

S. Sharpless completed a catalogue of 313 *H*II regions in the northern sky based upon the Palomar Sky Atlas prints. Approximately 300 early type stars associated with these nebulae have been listed. A solution was made for the position of the galactic pole with respect to the *H*II regions. The results differ from the I.A.U. pole by an amount which can be accounted for by known distortions in the outer part of the galaxy.

A study of M-type supergiants in the neighborhood of h-χ Persei cluster, was made by Sharpless using infrared spectra and two color photometry. Eight new red supergiant members of the double cluster were found. A comparison of these M-type supergiants with those associated with the 30 Doradus association made possible an independent determination of the distance of the Large Magellanic Cloud. A study of the distribution of M-type supergiants in other directions is in progress.

The scintillation program was continued. A. H. Mikesell developed portable measuring equipment for airborne use and A. A. Hoag devised a telescope which photographically indicates seeing by the Hartmann test principle. A report on effects of windtunnel air turbulence on seeing and scintillation was published.

Photographs of the sun were obtained on 307 days. The final reductions for the solar plates taken in July and August, 1957 were published in the *U. S. Naval Obs. Circ.* Nos. 86 and 87. Henceforth only the daily preliminary measures will be published. I. Lindenblad is in charge of this program.

Further progress was made in programming work for the IBM 650 Magnetic Drum Computer. In addition to improvements of programs developed earlier for the major computations of the Nautical Almanac Office, apparent place

computations, and the reductions of transit circle observations, other programs for various phases of work have been developed. Among the more important of these are programs for the reduction of double star measures, cluster proper motions, trigonometric parallaxes, photometric measures, asteroid plate measures, PZT observations, astrolabe observations, moon camera plate measures, and for numerical investigations of orbits needed in the study of the mass of Jupiter and for other investigations.

In addition to those already mentioned, the following publications by members of the staff appeared during the year:

G. M. Clemence: "Numerical Integration of the Orbits of the Principal Planets," *A. J.* **63**, 403, 1958; "Ephemeris Time," *A. J.* **64**, 113, 1959; "Dynamics of the Solar System," *McGraw Hill Handbook of Physics*, Part 2, Chapter 8.

R. L. Duncombe and G. M. Clemence: "Accuracy of the Solar Ephemeris," *A. J.* **63**, 456, 1958.

O. G. Franz: "The Triple System of Zeta Aquarii," *A. J.* **63**, 329, 1958.

A. A. Hoag, with Elske v.P. Smith: "Polarization in NGC 2244," *Pub. A. S. P.* **71**, 32, 1959.

Wm. Markowitz: "Use in Geodesy of the Results of Lunar Observations and Eventual Observations of Artificial Satellites," *Bulletin Géodésique*, issue 49, 33, 1958; "Geocentric Coordinates from Lunar and Satellite Observations," *Bulletin Géodésique*, issue 49, 41, 1958; "Variations in Rotation of the Earth, Results Obtained with the Dual-rate Moon Camera and Photographic Zenith Tubes," *A. J.* **64**, 106, 1959.

Wm. Markowitz and R. G. Hall, with L. Essen and J. V. L. Parry: "Frequency of Cesium in Terms of Ephemeris Time," *Physical Review Letters* **1**, No. 3, 1958.

A. H. Mikesell: "Wind Tunnel Tests of Stellar Scintillation," *Report of Aeronautics, Aerology Division*, March 1959.

E. Roemer: "Comet Notes," *Pub. A. S. P.* **70**, 326, 422, 514, 617, 1958 and **71**, 66, 180, 1959; *Harv. Announcement Card* Nos. 1651, 1658, 1660, 1666, 1668, 1669, 1677, and 1680.

S. Sharpless: "The Distribution of M-type Supergiants near h and χ Persei and 30 Doradus," *Pub. A. S. P.* **70**, 392, 1958.

K. As. Strand: "Stellar Motions in the Orion Nebula Cluster," *Ap. J.* **128**, 14, 1958.

K. Aa. Strand, with A. Lenham and T. Owen: "A Survey of Stars with Large Proper Motions in the Region of the Orion Constellation, *A. J.* **63**, 337, 1958.

C. B. Watts and A. N. Adams: "Meridian Observations of the Moon, 1953–1957," *A. J.* **63**, 299, 1958.

Edgar W. Woolard: "Inequalities in Mean Solar Time from Tidal Variations in the Rotation of the Earth," *A. J.* **64**, 140, 1959.

BYRON L. GURNETTE, *Captain, U. S. Navy, Superintendent*

Van Vleck Observatory, Wesleyan University, Middletown, Conn.

Personnel. The observatory staff during the year has consisted of Professors Thornton L. Page and Carl L. Stearns, Assistant Professor Charles E. Gasteyer, and, as secretary and computer, Mrs. Helen Dondero. Also, Messrs. William H. Jefferys, Anton G. Roos, and Michael R. Will have served as part-time undergraduate assistants. Mr. Stearns was on leave during the first semester.

On September 1, 1959, Dr. Heinrich K. Eichhorn will join the staff as associate professor.

Research. Mr. Page has extended his investigations of the masses of the double galaxies, and he presented the results as a paper at the Gainesville, Florida, meeting of the American Astronomical Society.

Mr. Stearns, Mrs. Dondero, and Mr. Will have continued the determination of stellar parallaxes from plates taken with the twenty-inch refractor. A paper summarizing the parallax measurements for twenty stars has been accepted for publication in the *Astronomical Journal*. This is the eighth in a series of such papers.

Also Mrs. Dondero and Mr. Stearns have prepared for publication a detailed discussion of the measurements and computations involved in all of our parallax work since the apparance of the first volume of the *Publications of the Van Vleck Observatory* in 1938.

Mr. Gasteyer has continued his work on double stars. About twenty double-star photographic plates were taken with the twenty-inch telescope. Eleven plates were measured and partially reduced by Mr. Jefferys. Observations made during the past five years, including about 200 plates fully measured and reduced, are being prepared for publication with the assistance of Mr. Roos.

Mr. Gasteyer has also continued his study of motions in the α Centauri system based on photographic plates taken at the Yale Southern Station and at the Cape Observatory. He presented the results of this investigation at the Gainesville meeting of the American Astronomical Society.

Equipment. Plans have been drawn for the construction of a new thirteen-foot dome near the western end of the observatory to shelter the six-inch Lerebours visual refractor, which will be completely remounted and made available for student use and for suitable research problems.

A five-inch Aero Ektar lens of forty inches focal length has been mounted on the tube of the twenty-inch telescope to replace the four-inch Voigtlander portrait lens. No definite program has been planned for this instrument, which was a gift from the Central Connecticut Amateur Astronomers.

CARL L. STEARNS, *Chairman*

Warner and Swasey Observatory, Case Institute of Technology, Cleveland, Ohio.

The research activities of the Warner and Swasey Observatory may be summarized as follows:

Objective Prism Surveys of Stars of High Luminosity. This is a long term program for surveying the complete northern sky with objective prism spectra. The Hamburg Observatory and the Warner and Swasey Observatory are cooperating in this task. The former will cover the sky from the North Pole to $+10°$ declination and the latter from $+10°$ to $-13°.3$ in declination.

Our principal aim is to produce a finding list for the following types of stars: OB stars in three luminosity groups, late B-type and A-type (including F-stars up to G0) supergiants. The catalogue will indicate the OB stars with emission in the ultraviolet. Since the sky will be covered with $H\alpha$-plates, stars showing this line in emission will be so indicated. The limiting photographic magnitude of the survey will be about 13.0. Approximate magnitudes of the stars will be given primarily to assist in their identification.

A $4°.5$ UV objective prism is used for the survey and a $4°$ flint objective prism for the $H\alpha$ survey. Through the courtesy of Dr. Goldberg and Dr. Miller, the Curtis Schmidt of the University of Michigan is being employed this summer by Mr. John Finnerty to obtain the $H\alpha$ plates. (Nassau, Stephenson and Stock).

OB Stars and Highly Luminous A-type Stars in Cygnus. An area of about 600 square degrees in Sagitta, Vulpecula and Cygnus has been surveyed with plates provided for us by the Hamburg Observatory. The total number of highly luminous stars in this region is about 1000 with a conspicuous concentration in the P Cygni area. About 25 percent of the stars of magnitude 12 and brighter show ultraviolet emission. The surface distribution of the luminous stars seems to indicate that the relative frequency of the different types differ from association to association. (Stock, Nassau and Stephenson).

The Distribution of A-type Stars in Selected Galactic Regions. The observational material in this investigation consists of the spectral plates taken for the study of the distribution of faint A-type stars in the Milky Way. The study seeks to determine the surface distribution of these stars in a number of selected regions of the Milky Way and to correlate the results with the galactic distribution of OB and M-giant stars. The possible clustering of A-type stars will also be considered.

The classification on available Hamburg Observatory plates of all recognizable late B and A-type stars covering a region of 25 square degrees which includes the IV Cygnus association has been completed. Some 1800 stars are involved in this study which reaches stars to the 12.5 photographic magnitude. (Nassau and Stephenson).

Spectral Characteristics of the Brightest Stars in Some Galactic Clusters. The spectral types and luminosity classes of the brightest stars in galactic clusters were determined from objective prism plates taken with the Hamburg Schmidt-type telescope. The region under survey extends $15°$ on either side of the galactic equator from $l = 15°$ to $l = 45°$. All clusters with unknown Trumpler types were considered and a few new clusters were added. (Stock and Roslund).

A Possible New Galactic Cluster Involving Delta Lyrae. Spectral types and approximate photographic magnitudes were determined for about eighty stars in the vicinity of δ Lyrae, from objective prism blue plates. The purpose of the work was to determine whether the apparent

clustering of early-type stars near δ Lyrae, noted by Gordon Grant, is a physical cluster.

Radial velocities are available only for δ^1 and δ^2 Lyrae and for one other star in the cluster, and the proper motions are too small to use them as a basis for judging cluster membership. The magnitude spectrum diagram for the cluster, however, strongly suggests that a real space concentration of stars in the vicinity of Delta Lyrae exists. This is of particular interest since δ^2 Lyrae is an M-type star (Stephenson).

Spectral Classifications in a Region in Cepheus. The stars of type A, gK, M, S and C in an area of twenty square degrees centered at RA = 23^h59^m; Dec = +66°.6 (1900) have been identified on spectroscopic plates. This is the region where a new group of OB stars associated with the emission nebula Cederblad 214 ab (*Lund Medd. Ser. II*, No. 119, 1946) was found at this observatory about a year ago (*A. J.* 63, 382, 1958). To the limit of the available plates, the A stars do not appear to show any concentration in the neighborhood of the OB association; on the contrary, a higher surface density of A stars is found in the regions outside the association than in it. This may be explained as caused by the absorption cloud in which the nebula is located together with an actual lack of clustering of A stars in the association. The M and C stars show the same effect, while the gK stars appear to be uniformly distributed. In the latter case the survey apparently has not reached as far as the association. A new S-star of about visual magnitude 15 was found, which, although not apparently related to the nebula, is of interest because it forms part of a group of four very close stars. (Blanco).

The Distribution of Stars in the Region of M8. Under the direction of Dr. Blanco, Mr. Pik Sin The, a graduate student from Indonesia, has carried out a study of the magnitudes and colors of stars in the surroundings of M8. The surface distribution of stars in various magnitude groups fails to show any concentration around the cluster NGC 6530 for stars fainter than $V = 12.5$. The stars in the contracting stage described by Walker (*Ap. J.* 125, 636, 1957) are in the faint magnitude groups which show a lack of clustering. This result is in agreement with Wallenquist's findings (*Uppsala Ann.* 1, No. 3, 1940). Color magnitude diagrams for stars in areas quite distant from NGC 6530 resemble, for stars of V magnitude 12.5 or fainter, that found in the cluster by Walker. A Wolf diagram of red-giant stars prepared from observations of the obscured area surrounding NGC 6530 and a neighboring clear region shows the total absorption of the dark cloud to be 1.7 visual magnitude and its distance to be about 1.3 kpc. The present data indicate that NGC 6530 consists only of a concentration of stars earlier than A0 and of faint variables and H-alpha emission objects. The stars found above the main sequence by Walker may be distant stars reddened by the cloud that serves as a backdrop to NGC 6530. If we assume normal interstellar absorption, the ratio of color excesses for the stars behind the dark cloud can be computed from the total absorption found in the Wolf diagram. With this ratio, the Q method may be applied to Walker's photoelectric observations. The results, however, may be sensitive to any systematic errors present in Walker's U magnitudes.

Relatively Cool Stars in Galactic Clusters. The systematic search for M, S and carbon stars in seven galactic clusters was undertaken in collaboration with Dr. Nassau during the summer of 1958. They are: NGC 129, M25, NGC 7790, NGC 188, NGC 752, M11, and NGC 7789.

The establishment of the existence of such stars in these clusters is of considerable interest because of its direct bearing on stellar evolution. Provisional results were obtained for two of these clusters. In NGC 7789 two M stars, an S-type star, and a Carbon star were found as probable members of this cluster, and in NGC 7790 one M-type star was found. (Mavridis).

A Study of the Spectral Changes of Red Variables. The study of the infrared spectral variations of red variable stars at different phases is being continued. The list of the 51 stars under study is given in the 1958 Draft Report of the I. A. U., page 231. (Nassau).

A Search for White Dwarfs in the Coma Galactic Cluster. A search for white dwarfs in the Coma galactic cluster by means of three-color photography is being carried out. This cluster has been thought to have eight or nine white dwarfs, as predicted. Preliminary results here indicate that only two of these eight or nine are probable white dwarfs. However, three other possible white dwarfs are also present in the direction of the cluster. Two of these have been found on a Tonantzintla survey like the present one, and one is new. Comparable numbers of stars, bright in the ultraviolet, were found in several nearby

comparison fields, so that the membership of the Coma objects in the cluster cannot be established from the available data. (Stephenson).

The Giant-Dwarf Ratio Among G5 Stars. A statistical study of the proper motions, radial speeds, and apparent magnitudes of the 6th magnitude G5 stars has shown that 25 per cent of these are dwarf stars. The calculations required have been performed with the IBM 650 Magnetic Drum Computer. Programs for this work for use by other investigators are available. (McCuskey).

A Theoretical Study of Some Characteristics of Objective Prisms. Certain characteristics of objective prisms such as the variation of the dispersion across the field and the field distortions on the plate caused by the prism have been investigated on a theoretical basis. The work is completed and is ready for publication. (Stock and Upgren).

Miscellaneous. The chapter on Photography and Photographic Photometry for the Compendium of Astronomy and Astrophysics Vol. II by Stock and Williams has been submitted for publication.

New Facilities. The acquisition of the ultraviolet objective prism has materially extended the scope of our investigations. It has a 24-inch clear diameter, a 4°.5 angle, and was made of UBK7 glass. When attached to the Burrell-Schmidt telescope it gives a dispersion of 580 Å/mm at $H\alpha$. With normal exposure, the spectra extend to nearly 3300 Å. When combined with our 2° flint prism, it is possible to obtain spectra in the infrared at extremely low dispersions. The identification of late M stars with a dispersion of more than 5000 Å/mm at the A-band is possible. The Perkin Elmer Corporation did the optical work and the Warner and Swasey Company made the cell. The National Science Foundation provided the funds for the prism.

Staff. After 35 years as Director of the Observatory and Head of the Department of Astronomy, the writer has resigned these duties which are to be taken over by Professor Sidney W. McCuskey beginning July 1, 1959. However, the writer will continue his duties as Professor of Astronomy. Dr. Stock resigned his position in order to accept an appointment at the Yerkes and McDonald Observatories. Dr. Stephenson was promoted to the rank of assistant professor and Mr. John Finnerty to the rank of associate astronomer. Dr. L. Mavridis of the University of Thessalonika, Greece, concluded his appointment as a Cleveland Astronomical Society Fellow on December 31, 1958. Mr. Curt Roslund of the University of Lund, Sweden, was appointed to this fellowship beginning April 1, 1959. Dr. Ulf Sinnerstad of the Stockholm Observatory spent February and March primarily studying objective prism spectra. Mr. Pik Sin The spent a year of graduate study under the sponsorship of the International Cooperative Administration.

Visitors who gave colloquia at the Observatory included: Sir Harold Spencer Jones, Dr. Helmut Abt, Dr. Geoffrey Keller, Dr. Leona Marshall, Dr. Walter Fricke, Dr. L. Plaut, Dr. Margaret Burbidge, Dr. Arne Slettebak, and Dr. G. M. Clemence.

Publications. The following papers were published during the year:

Reprint No.

86. M-Type Stars and Red Variables in the Galactic Center, J. J. Nassau and V. M. Blanco, *Ap. J.* **128**, 46, 1958.
87. The Distribution of the BD M-Type Stars Along the Galactic Equator, Heinz Neckel, *Ap. J.* **128**, 510, 1958.
88. Calibration Curves in Focal Photographic Photometry, Jurgen Stock, *A. J.* **63**, 496, 1958.
89. Stellar Spectra in Milky Way Regions. VII. A Region in Auriga. VIII. A Region in Orion, S. W. McCuskey, *Ap. J.* Supplement No. 35, **4**, 1, 1959.
90. An Infrared Survey of a Region in Cygnus, B. Westerlund, *Ap. J.* Supplement No. 37, **4**, 73, 1959.
91. Peculiar and Metallic-Line A-Type Stars in a Galactic Zone, A. Slettebak and J. J. Nassau, *Ap. J.* **129**, 88, 1959.
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J. J. NASSAU, *Director*

Yale Observatory, Yale University, New Haven, Conn.

Personnel. Dr. Ida Barney resigned from active duty at the end of the academic year after having served the Observatory for 37 years. Her principal contributions to astronomy during this long period are contained in 22 volumes of the *Transactions of the Yale Observatory*, which present the results of the Yale zone catalogue project, begun at the initiative of the late Frank Schlesinger. Miss Barney participated in this project since its beginning, and carried it forward after Schlesinger's retirement in 1941. The success of the project is, therefore, primarily due to Miss Barney's activity and her perseverance in overcoming numerous obstacles.

Dr. A. Edward Lilley resigned at the end of the academic year to assume an appointment to associate professor at the Harvard College Observatory and director of the Agassiz Station Radio Astronomy Laboratory.

Dr. Boris Garfinkel, chief analyst at the Army Ordnance Ballistic Research Laboratories, Aberdeen Proving Grounds, Maryland, was appointed research associate. He collaborated with Mr. Brouwer on a research project on artificial satellite motion supported by a contract with the Air Force Cambridge Research Center, Bedford, Massachusetts.

Zone Catalogues. Volumes 26II and 27 of the *Yale Observatory Transactions* came from the printer at the end of the academic year. These volumes, under the authorship of Ida Barney, Dorrit Hoffleit and Rebecca B. Jones, contain new positions and proper motions of 16,544 stars in declinations $+50°$ to $+60°$. The work was done in cooperation with the Watson Scientific Computing Laboratory of the International Business Machines Corporation. The support of this undertaking by Dr. W. J. Eckert, director of the Watson Scientific Computing Laboratory is gratefully acknowledged.

Work has continued on the operations preparatory to the measurement of a series of zone plates in declinations $-30°$ to $-40°$. The punching of the data from the Cape Catalogue volumes for these declinations has been completed. A program for converting right ascension and declination to rectangular coordinates on the plates was written by Dr. Morris S. Davis for the IBM 650. It was applied to one plate which was subsequently used for trial measurements at the rehabilitated measuring machine. Mrs. Mary E. Mullally and Mrs. Celia T. Pettit have been principally responsible for this activity, under the supervision of Dr. Dorrit Hoffleit.

The Parallax Program. Only 265 plates for the parallax program were measured during the year; 144 by Mrs. Mary E. Mullally, 121 by Mr. D. S. Kimball. Both measurers were occupied with other observatory duties during most of the year. Miss Louise F. Jenkins continues the general supervision of this work.

Mr. Davis supervised the writing of an IBM 650 program for the computations of parallax solutions from the plate measurements. The saving of time is so considerable that it was decided to use this as the standard method for future solutions.

Celestial Mechanics. Miss Jocelyn R. Gill completed her discussion of the observations of Neptune's satellite, Triton, and received her Ph.D. degree in June. Before publication of her results she intends to add the discussion of recent observations made with the Yale Telescope at Mount Stromlo.

Mr. and Mrs. Jean Kovalevsky left New Haven in February, 1959 to return to the Paris Observatory. Mr. Kovalevsky had essentially completed his study of the motion of the eighth satellite of Jupiter.

Mr. Brouwer completed a solution of the motion of an artificial satellite without drag. After experimentation with Delaunay's method he decided on the use of von Zeipel's modification of this method, which turned out to have significant advantages for the solution of this problem.

Dr. Boris Garfinkel continued his study of the artificial satellite problem by the method published by him in *A. J.* **63**, 88, 1958.

Theoretical Astrophysics. Using electronic computers (IBM-650 at Yale, IBM-704 at MIT) Mr. M. Vardya computed a set of 33 adiabats for hydrogen-helium mixtures with abundance ratios 8/1, 16/1, and infinity. The underlying expression for the adiabatic gradient takes complete account of the formation of hydrogen molecules and its interlocking in the ionization of hydrogen and helium. The adiabats so obtained cover the range of temperatures and pressures realized in late-type stellar envelopes. An unexpected result of these integrations is the existence of a moderate fraction of hydrogen molecules at temperatures exceeding 10,000°K.

Mr. Vardya and Dr. Wildt have shown that by including the effects of hydrogen molecules it is possible to remove qualitatively a discrepancy in the theory of stellar models of red dwarfs which Osterbrock and Limber had to leave unresolved. The quantitative test must await construction of new model atmospheres for red dwarfs. Preparation of the necessary numerical data has been completed, and work along these lines will be continued by Mr. Vardya, who received his PhD. in June.

Radio Astronomy. Dr. Harlan J. Smith and Mr. J. N. Douglas, ably assisted by Mr. K. Philip and undergraduate students, continued the activity in planetary radio research. During the year the monitoring equipment in all six of the contemplated frequencies (13.25, 16.5, 19.2, 20.0, 22.2 and 23.0 Mc) was essentially completed. It included the construction of four new radiometers, and two new antenna fields for the lowest frequency interferometers, with the aid of funds provided by grants from the Research Corporation and the National Science Foundation.

Calibration equipment was installed and the entire observing installation moved from Hendrie Hall in New Haven to Bethany.

Jupiter has exhibited increased activity in the monitored frequencies after a period of relative quiescence around sunspot maximum. Saturn remains a possible source, with several events very difficult to ascribe to Jupiter, but none of these are conclusive.

Mr. Lilley's activity in radio astronomy in the field of very low frequencies increased rapidly during the year. Under a contract with the Air Force, and with the close cooperation of Mr. Douglas, radio telescopes for satellite transportation and lunar and planetary probes are being constructed. The first telescope is expected to be launched in a sounding rocket by the beginning of 1960.

With the aid of a research grant by the National Aeronautics and Space Administration, Mr. Lilley and Mr. Brouwer worked on the early stages of a project of evaluating the distance from the earth to the sun by the measurement of the earth's orbital velocity from Doppler shifts in the frequency of the 21 cm hydrogen line.

Mr. Lilley's research received continued support from the Research Corporation and an Alfred P. Sloan Research Fellowship.

Instrumental. The Catalogue Camera was thoroughly overhauled during the year. A new, much improved, photoelectric photometer was built for the Butler Telescope by two undergraduate students, R. Boynton and J. McCullough.

Miscellaneous. Cataloguing of the Observatory Library books and serials by personnel of the University Library was essentially completed during the year.

A rapid turnover in editorial assistants was the primary difficulty in the operation of the editorial office of the *Astronomical Journal.* Untiring efforts of Mr. Smith, assisted by Mrs. Mary S. Albee, overcame most of the resulting delays in publication schedule. The Council of the American Astronomical Society appointed Mr. Smith co-editor of the *Astronomical Journal,* with Mr. Brouwer.

Mr. D. S. Kimball continued his association with Dr. C. W. Gartlein at Cornell University on the study of the aurora borealis as a phase of the International Geophysical Year.

DIRK BROUWER, *Director*

ONE HUNDRED–THIRD MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY, TORONTO, ONTARIO, CANADA, AUGUST 30–SEPTEMBER 2, 1959

ABSTRACTS OF PAPERS PRESENTED

Athay, R. Grant. *Anomalous broadening of the* CaII *K line in spicules.*

Observations of the profiles of the $H\alpha$, $H\beta$, $H\gamma$, D_3 and K lines for polar spicules suggest a spicule model in which the hydrogen, HeI and CaII atoms producing the observed lines are well-mixed, but in which the CaII ions have a non-thermal component of velocity not shared by hydrogen and HeI. An alternative model in which the hydrogen and CaII atoms producing the Balmer lines and the K line are physically separated by temperature stratification from the HeI atoms producing the D_3 line satisfies some aspects of the data and allows hydrogen and CaII to share the same non-thermal velocity field. However, this alternative model is not compatible with the relative intensities of the $H\alpha$ and D_3 lines, nor with the absence of the strong lines of such ions as SrII and TiII.

The $H\beta$, $H\gamma$ and D_3 profiles are gaussian, and for the majority of spicules the half-widths for a given line are the same to within the probable errors in the observations. The profiles of these lines indicate a kinetic temperature of 50,000° and a non-thermal velocity component of about 7 km/sec. The $H\alpha$ profile is apparently broadened to some extent by self-absorption, which is consistent with the above model. The K line, however, appears to be broadened by a non-thermal velocity component of about 30 km/sec, which corresponds to the mean spicule velocity. It is suggested that the broadening of the K line is due either to the spiralling of the CaII ions about magnetic lines of force oriented at some angle to the spicule motion, or to the forced oscillations of the CaII ions by perturbations in a magnetic field lying in the direction of the spicule motion.

High Altitude Observatory
University of Colorado
Boulder, Colo.

Bahng, J. D. R., Danielson, J. B., Rogerson, J. B., Jr. and Schwarzschild, M. *Sunspot photographs from the stratosphere.*

The 12-inch telescope used during the balloon flights in 1957 has been modified by adding a television link so that the astronomer on the ground can see what the telescope is photographing, and by adding a radio command so that the astronomer can focus the telescope and direct it to any place on the solar disk during the flight.

On the first flight this season the television and command links worked satisfactorily but instrumental vibrations and dust on optical surfaces limited the number and usefulness of the high-definition photographs obtained. However, before the next flight both these disturbances were greatly reduced and on the second flight (Aug. 17, 1959) a large number of high quality photographs was obtained.

Time sequences were taken, both of granulation far from sunspots and of sunspots with their immediate surroundings. The time variations of the granules as well as of the penumbral filaments are clearly visible. A highly preliminary inspection of the photographs suggests that the granulation directly adjacent to sunspots does not seem to differ strikingly in size or lifetime from those in undisturbed regions.

Project Stratoscope is sponsored jointly by the Office of Naval Research and the National Science Foundation.

Princeton University Observatory
Princeton, N. J.

Bakos, Gustav A. *The color-magnitude diagram of visual binaries.*

Photoelectric colors and magnitudes on the B, V system have been obtained for 75 visual binaries. Absolute visual magnitudes have been determined spectrographically for all the primary stars. This and the known apparent magnitude difference between the components fixed the absolute visual magnitude of the companion.

Because of the selection factor the primary components of visual binaries are generally late type stars, giants or supergiants. The secondary components, with a few exceptions, are concentrated along the main sequence. This main sequence deviates slightly from the zero-age main sequence.

When visual binaries are considered in the

light of an age sequence (as outlined by evolutionary tracks of galactic clusters) both young and old binaries are represented. A group of visual binaries has been identified where one (the fainter) or both components are still in the stage of gravitational contraction. For the majority of stars an age of 5×10^9 years has been postulated. However, there are indications that a few stars may be as old as 10×10^9 years. Cases where the secondary components are situated above or below the main sequence can also be understood on the basis of stellar evolution.

Research for this work was done at David Dunlap Observatory.

Smithsonian Astrophysical Observatory
Cambridge, Mass.

Beals, C. S. and Millman, P. M. *A comparison of sub-surface materials from two meteorite craters.*

The non-meteoric sub-surface materials of the Barringer and Holleford Craters have been compared on the basis of extensive sampling for each crater. With the co-operation of the Barringer Crater Company, specimens of material were collected from various positions in a shaft 50 ft deep, located 500 ft from the center of the Barringer Crater, and also from a horizontal tunnel, 350 ft long, whose entrance was on the inner wall 1,350 ft from crater center at a vertical depth 350 ft below the rim.

The specimens contained particles ranging in size from irregular pieces several inches across down to microscopic grains of dust. The grain size distributions for eight samples were determined by the Division of Building Research of the N.R.C. and several types of grain size distribution curves were found.

Drill cores were obtained from the Holleford crater at distances of 1400, 2500, and 3750 ft. from the center and at depths varying from 65 to 1128 ft. Particle sizes ranged from gross rocks down to microscopic grains only clearly visible in thin sections.

A mixture of materials from the Barringer crater was set in cement and drilled. The resulting artificial cores showed a remarkable similarity to the drill cores from Holleford, the main difference being the darker color of most of the materials from the latter crater. General studies of the nature of the rock fragments including thin sections of cores from both craters suggest that the sub-surface materials were produced *in situ* with a minimum of subsequent transportation by wind and water.

These observations reinforce evidence from depths, diameters and profiles (Beals 1958) indicating that the mechanical process responsible for shattering the rock and hollowing out the depression was the same for both craters.

REFERENCE

Beals, C. S. 1958, *Sci. Amer.* **199**, 39.

Dominion Observatory and
National Research Council
Ottawa, Ont., Canada

Broten, M. W. and Medd, M. J. *Absolute flux measurements of radio sources at 9.37 centimeters.*

Measurements at a wavelength of 9.37 cm of the absolute flux level of the brighter radio sources were made during 1959 at the National Research Council's radio observatory near Ottawa.

The radiometer consists of a traveling-wave-tube receiver having a bandwidth of 450 Mc/s centered on 3200 Mc/s. The sensitivity is sufficient to allow observations to be taken with a ten-foot parabolic reflector as telescope. The experimental procedure eliminates the necessity of measuring the background radiation; the effective antenna temperature was determined by comparison with a heated resistive element or hot load; and the gain function of the reflector was obtained by comparing the antenna temperatures derived from daily measurements of solar emission with the reflector and with a 4-foot by 3-foot aperture standard horn. By this method it is estimated that a probable error of about five per cent may be assigned to the flux values of the radio sources.

In units of 10^{-25} watts/m^2/c.p.s. (two polarizations) values of flux for Taurus A, Cygnus A, and Cassiopeia A, are respectively: 71, 67, and 132.

Radio and Electrical Engineering Division
National Research Council
Ottawa, Ont., Canada

Brownlee, Robert R. and Cox, Arthur N. *Time-dependent stellar models.*

High speed computing machine calculations of solar mass interior models are described for two cases. The method of obtaining the two

models involves relaxation of an arbitrary starting configuration. The integrations over time are made considering the usual non-linear hydrodynamic equations simultaneously with energy production and energy flow equations. The time scale of the hydrodynamics is arbitrarily increased in these calculations to allow simultaneous relaxation of hydrodynamic and thermal properties to the static state. Also to dampen initial oscillations, a viscosity is added. It is possible to watch the time history during the relaxation and note the time when there are no more motions. The resulting equilibrium models compare well with other recent solar models considering the differences in opacity and energy generation formulae. Our slightly higher opacities result in a small convective core for these models.

Los Alamos Scientific Laboratory
University of California
Los Alamos, N. M.

Bruton, R. H., Craig, K. J. and Yaplee, B. S. *The radius of the earth and the parallax of the moon from radar range measurements on the moon.*

From a limited amount of lunar radar range data taken by the Radio Astronomy Branch of the Naval Research Laboratory during October and November 1957, the following value for the mean center-to-center distance to the moon, s, has been determined.

$$s = 384{,}402{,}000 \pm 2100 \text{ meters}$$

Using this radar-determined distance along with the dynamical and geometrical relationship for the moon's mean parallax and the best known values for the various constants involved, the following values for the mean equatorial radius of the earth, a, and the mean equatorial horizontal parallax of the moon, π_ζ, have been derived.

$$a = 6{,}378{,}125 \pm 68 \text{ meters}$$

$$\pi_\zeta = 3422''.571 \pm 0''.047$$

The uncertainties given are standard deviations.

Residuals of measured distance minus the distance computed using parallax values from the Improved Lunar Ephemeris show unexplained monthly and daily variations.

U. S. Naval Research Laboratory
Washington, D. C.

Burke, B. F. and Firor, J. W., Jr. *Transit observations at 405 Mc/s.*

Right ascensions of the brighter radio sources have been measured as the first phase in a program to improve the accuracy of radio source positions. The apparatus was a 60° corner reflector containing 256 full-wave dipoles tuned to a frequency of 405 Mc/s and symmetrically feed by a branching feeder system. The resulting fan beam measures 12.9 minutes of arc by 20 degrees to half power points, with greatest resolution in right ascension. From the symmetry of the array, level and azimuth errors are determined by construction tolerances, and are believed to be less than 10 seconds of arc. Accuracy of collimation is largely limited by the symmetry of the transmission lines in the feeder system, and was checked observationally by comparison of apparent radio right ascension with that of the optical objects for the sources Tau A, Vir A, Cyg A, and Cas A. A collimation error of $\frac{3}{4}$ minute of arc is indicated. When this error is removed the resulting differences between radio and optical right ascension are less than $\frac{1}{4}$ minute of arc for these four sources.

A number of galactic sources are resolved in right ascension, the most interesting of these being the source Sgr A, often identified with the galactic center. Our results show asymmetrical structure, much like that observed by Drake at 3 cm with the NRAO 85 foot telescope. Exact intercomparison is difficult because of the broad disc component of the galactic background, which must be removed from the 405 Mc/s data, but it appears that the brightest features have similar spectra, and are probably non-thermal, although the spectral index is close to zero. The right ascension of the brightest feature is $17^h42^m41^s$ (1950.0).

Department of Terrestrial Magnetism
Carnegie Institute of Washington, D. C.

Cameron, A. G. W. *Pycnonuclear reactions and nova explosions.*

At very high densities electron shielding cuts off nuclear Coulomb potential barriers very close to the nuclear surface. Under these circumstances the classical turning points of low energy ions are very insensitive to the bombarding energy. Under such conditions nuclear reaction rates become very insensitive to temperature and very sensitive to density. They can be

called pycnonuclear reactions (Gr. *pyknos*, compact, dense). Nuclear reaction rates as functions of temperature and density have been calculated by double numerical integration of the barrier penetration probability for the following reactions: the three-alpha process, $C^{12}(\alpha,\gamma)O^{16}$, $N^{14}(\alpha,\gamma)F^{18}(\beta^+\nu)O^{18}$, and $O^{16}(\alpha,\gamma)Ne^{20}$. Pycnonuclear ignition takes place when a degenerate gas increases in density until nuclear energy generation exceeds the transport of energy from the gas; then heating must be followed by a (possibly explosive) expansion of the gas. The results show that the $N^{14}(\alpha,\gamma)F^{18}(\beta^+\nu)O^{18}$ reaction will probably be the ignition process responsible for core expansion at the tip of the red giant sequence in Population I stars. The $C^{12}(\alpha,\gamma)O^{16}$ reaction may be the principal ignition process initiating nova explosions. Under reasonable conditions it can still ignite explosions in predominantly helium stars of half solar mass.

Atomic Energy of Canada Ltd.
Chalk River, Ont., Canada

Coates, Robert J. *The lunar brightness distributions at 4.3-mm wave length.*

At millimeter wave lengths the brightness distribution on the moon varies with the lunar phase and is a function of the observing wave length. Determinations of the wavelength dependence will make it possible to compute some of the physical characteristics of the lunar surface. Observations were made at a wave length of 4.3 mm, one half the wave length used for previous observations by Gibson (1958). Television-type scans were made across the lunar disk at different phases with an angular resolution of 6.7 minutes of arc, which was sufficient to resolve some of the large features on the moon. Maps of lunar brightness made from the multiple scans show distinct features with different brightness characteristics. Some are hotter and some are colder than the surrounding areas. The magnitude of the phase variation of the brightness measured at 4.3-mm wave length is larger than that observed at 8.6 mm.

REFERENCE

Gibson, J. E., 1958, *Proc. Inst. Radio Engrs.* 46, 280.

U. S. Naval Research Laboratory
Washington, D. C.

Coates, R. J., Covington, A. E. and Edelson, S. *The 4.3-mm and 10.7-cm outbursts of June 9, 1959.*

On June 9, 1959 at 16:52 UT a burst of solar radiation was recorded at the wave length of 4.3 mm at the U. S. Naval Research Laboratory. This is the first detection of a burst at such a short wave length. Simultaneously, a large outburst was recorded on 10.7 cm at the National Research Council, Canada. The peak flux at 4.3 mm was 500×10^{-22} w m^{-2} cps^{-1} as compared with 2000×10^{-22} w m^{-2} cps^{-1} at 10.7 cm.

Previous studies have shown that almost every time a short-wave-length radio burst occurs, there is also a coincident $H\alpha$ flare or surge, and the large outbursts are coincident with high importance flares. The June 9 event is significant because there was no $H\alpha$ flare on the disk at the time of the radio outburst. A high-resolution scan at 10.7 cm made at the time of the outburst shows that the emitting region was at the approximate position of N18E90. There was a very faint jet visible on the $H\alpha$ spectroheliograms coincident in time with the outbursts and at the radio position. At 17:40 UT a second intense radio outburst occurred and there was a very bright ejection from the same position on the east limb. The base of these ejections, in both cases, appeared to be beyond the limb on the back side of the sun. This region remained active as it rotated onto the front of the sun and it was possible to determine its position on June 9. Using this position and the known heights of the radio limb of the sun of $.0057R_\odot$ at 4.3 mm and $.03R$ at 10.7 cm, the minimum height of the emitting region was determined to be 20,000 ± 10,000 km and 37,000 ± 10,000 km respectively. These are lower limits only; the actual emitting regions may have been located at much greater heights.

U. S. Naval Research Laboratory
Radio Astronomy Branch
Washington, D. C., and
National Research Council
Ottawa, Ont., Canada

Cook, Allan F. *Shielding of meteoroids by vaporization.*

It has been shown by Levin and also by Öpik that shielding of a non-vaporizing meteoroid by air molecules re-emitted from its surface at the surface temperature is negligible so long as the

diameter of the meteoroid is less than one mean free path in the air for a molecule travelling at very high velocity. This result is valid in spite of the fact that on the average such a re-emitted molecule suffers a collision with a free air molecule after travelling a distance from the surface which is very short compared to the mean free path in the air. The essential cause is that these collisions frequently eject the reemitted molecules laterally at high speeds beyond the edges of the meteoroid. Both Levin and Öpik have claimed that a similar process operates for vapors emitted from the meteoroid. In the case in which large numbers of meteoric molecules are emitted from the surface it can be shown that these can accumulate to the point where they stop the air stream ahead of the meteoroid and form a shield which transfers the kinetic energy thus acquired at its leading surface via a temperature gradient established in that shield both to the laterally outflowing meteoric vapor and to the surface of the meteoroid. The claim of Levin and of Öpik is justified for extremely slow meteors moving at speeds near 12 km/sec. At very high velocities near 72 km/sec the vaporizing meteoroid's diameter must be less than one twentieth of a mean free path of a very high velocity meteoric molecule in air in order that shielding by its own vapors shall be negligible. The dependence of the heat transfer coefficient on diameter of the vaporizing meteoroid, in the range in which shielding by its own vapors is significant while shielding by an air cap is negligible, runs approximately as the inverse 0.4 power.

Harvard College Observatory
Cambridge, Mass.

Cook, A. F. II, Hawkins, G. S. and Steinon, F. M. *The width of meteor trails II.*

A detailed comparison is made between the images of meteor trails and star trails. The photographs were obtained by A. F. Cook during the Geminid shower of 1957 using the 48-inch Schmidt telescope on Mt. Palomar. Adjustments were made in the focal setting of the telescope to allow for the fact that the meteors were not at infinity. Microdensitometer tracings showed that the intensity distribution in the images was gaussian and the widths were measured at the point where the intensity had decreased by a factor of $1/e$. A significant difference in width was found between in-focus meteor images and the in-focus star images. The average width of the Geminid meteors was found to be 3 meters and the average magnitude was +4. One meteor, magnitude 0, showed a width considerably in excess of this value, splitting into three fragments which had separated by as much as 20 meters at the end of the trail. A trail width of several meters is inconsistent with the assumption that meteors are small solid bodies. It is consistent with the dustball hypothesis in which severe fragmentation takes place as the meteor body is disrupted in the upper atmosphere.

Harvard College Observatory
Cambridge, Mass.

Cuffey, James. *NGC 6838.*

NGC 6838 is one of the richest of the clusters listed in the catalogues of galactic clusters. Because the brightest stars were red and the fainter ones bluer, it was suspected by many to be a globular cluster. Since it is strategically located near the direction toward which the stars in the solar neighborhood are moving under galactic rotation, it is especially desirable that its true nature be known.

A study of the color-magnitude diagram, based on plates taken with the 100-inch Mt. Wilson reflector and photoelectric standards observed with the 82-inch McDonald telescope, shows that although the brightest stars are red and the fainter stars become bluer with decreasing brightness, the cluster is not a typical globular. The red giant branch is characterized by wide scatter and is poorly defined. The horizontal white branch is missing, and no very blue stars are present. No cluster-type variables are present. Thus, the cluster lacks most of the attributes now regarded as appropriate to the color-magnitude relation of a typical globular cluster.

Goethe Link Observatory
Indiana University
Bloomington, Ind.

Demarque, Pierre. *The structure of subdwarf stars.*

It is generally accepted that the subdwarfs are characterized by a low metal abundance. The present investigation indicates that the helium content also plays a role in differentiating among subdwarfs.

Interior models for subdwarf stars were constructed assuming a low heavy-element content, i.e., $Z = 0.001$, for masses ranging from 0.6 to 1.0 solar mass, and hydrogen content varying from 0.75 to 0.999 by weight. The models have a structure similar to that of red dwarf stars, investigated by Osterbrock: they have a radiative core and a convective envelope in adiabatic equilibrium. The energy production was assumed to be due to the proton-proton reaction, and Keller and Meyerott's tables were used for the opacity.

In order to determine the depth of the convective zone, and therefore the position of the star in the H-R diagram, the outer boundary conditions as given by the physical conditions in the subphotospheric layers must be determined. In the atmospheres of stars with effective temperatures in the vicinity of the sun's, the temperature gradient does not approach the adiabatic gradient as soon as convection sets in. There is therefore an intermediate zone where one has to take into account the effect of the superadiabatic gradient. Such model atmospheres were constructed, making use of the theory of the mixing length as developed by Biermann.

Both cores and atmospheres were integrated with the help of the University of Toronto IBM 650 computer.

The resulting models are situated in the subdwarf region of the theoretical H-R diagram. One notices that for a given mass the helium content strongly affects the radius and therefore the effective temperature, in the sense that abundant helium makes for a smaller star with higher surface temperature. Unfortunately, comparison with observation is difficult because the actual position of observed subdwarfs in the $\log \frac{L}{L_\odot} - \log T_e$ diagram is still uncertain. The results can be used to estimate the masses and helium content of stars in globular clusters.

David Dunlap Observatory
Richmond Hill, Ont., Canada

Dennison, Edwin W. *Preliminary experiments with a T.V. image tube for solar photometry.*

Photo-electric surface photometry has two outstanding advantages over photographic photometry: (a) increased sensitivity and (b) linearity of response. Experiments to use these advantages in solar research are being conducted by the Sacramento Peak Observatory. The first advantage, namely increased sensitivity, will enable us to observe the spectrum and monochromatic images of solar phenomena with considerably shorter exposure times than are now being used. Until the introduction of the G.E. type 5294 Image Orthicon it was difficult to expose the photo-cathode for periods of time longer than 1/30 second. Now exposures of at least a second and probably longer will be possible. In addition it is now possible to separate the exposure and readout cycles. This will enable us to adjust the exposure time for optimum signal-to-noise ratio and also to reduce the effects of poor seeing by using shorter exposure times.

The second advantage, namely, linearity of response, will be used to generate isophote contours during the readout process and as a result will plot isophotes directly on the viewing screen, thereby eliminating the necessity for laborious photometric reduction. Other forms of presentation can be used which will preserve the linearity of response of the photo-electric system.

Sacramento Peak Observatory
Sunspot, N. M.

de Vaucouleurs, G. *Rotation and mass of the Large Magellanic Cloud.*

New optical velocities of 7 outlying emission nebulosities observed with the 2-prism Zeiss spectrograph of the Mount Stromlo 74-inch reflector are used in conjunction with the old Lick velocities of 17 objects for a rediscussion of the rotation curve and a revision of the mass estimate $\mathfrak{M} = 0.3 \cdot 10^{10}$ solar masses previously derived from the Sydney radio observations (Kerr and de Vaucouleurs 1956). If $m_o - M = 19.0$ and $i = 63°$ the maximum rotational velocity is $V_r = 145$ km/sec at $r = 3.°5$ and the revised mass is $\mathfrak{M} = (2.5 \pm 0.5) \cdot 10^{10}$ solar masses. The absorption-free mass-luminosity ratio $\mathfrak{M}/\mathfrak{L}$ is about 6 and the ratio of neutral hydrogen mass to total mass $H_I/\mathfrak{M}$ is 4 to 5 per cent.

The large discrepancy between radio and optical results in part from a change in the adopted distance (63 kpc vs. 46 kpc in 1956), and in larger part from the interpretation of the data. This interpretation should be greatly assisted by the new radio observations currently planned at Sydney.

REFERENCE

Kerr, F. J. and de Vaucouleurs, G. 1956, *Australian J. Phys.* 9, 90.

Harvard College Observatory
Cambridge 38, Mass.

Dieter, Nannielou H. *Neutral hydrogen in OB associations.*

Analysis of the line profiles of the neutral hydrogen survey of the galactic plane published by Muller and Westerhout has shown many cases in which neutral hydrogen appears within OB associations. Intensity contour diagrams of regions including such associations have been constructed from the line profiles for different velocities. In Morgan's unpublished catalogue of OB associations 31 are listed which occur within the limits of the Leiden survey, and for 25 of these some measure of the radial velocity is available from optical observations. For 20 of these associations a well-defined maximum in the equal-intensity contour diagrams occurs at the velocity of the association and does not occur at other similar velocities. For the remaining six associations a maximum occurs at a particular velocity, but no identification of the gas with the association can be made without stellar radial velocity measurements.

The distance of a hydrogen cloud may be estimated from the distance of the association and from its velocity and a model of galactic rotation. Comparison of the distances from the two methods shows many large discrepancies.

The contour diagrams show that the maximum in the equal-intensity contours changes its longitude continuously in one direction as the velocity changes. In each of the twelve cases in which it is possible to follow the maximum through such a progression this direction is consistent with the effect of the shearing action of galactic rotation.

Geophysics Research Directorate
Air Force Cambridge Research Center
Bedford, Mass.

Drake, F. D. *A high-resolution radio study of the galactic center.*

A radio map covering five square degrees in the region of the galactic center has been made, using the 85-foot reflector of the National Radio Astronomy Observatory. A travelling-wave tube receiver operating at 8000 Mc/s was used, and the antenna beamwidth was about 7 minutes of arc. The map shows regions of radio emission apparently connected with the emission nebulosities observed optically in the vicinity of the galactic center. It is evident that these *H*II regions contribute only a very small amount of radio emission to the Sgr A source, and are not a part of the galactic nucleus. The nucleus itself consists of two bright regions of emission situated about 10 and 19 parsecs from the galactic center, and lying in the galactic plane, and two more distant regions at a distance of about 90 parsecs from the galactic center, situated symmetrically about the center and lying in the galactic plane. From the symmetry in the outer sources, it is suggested that they actually represent the projection of a ring of emission surrounding the galactic center.

Using the above described structure of the nucleus, previous observations of this region are reanalyzed so as to give flux density values for the four major emitting regions. It is found that the center two sources have thermal spectra, while the outer two have nonthermal spectra with spectral index 0.7. The inner two sources are interpreted to be *H*II regions. The brighter has a minimum emission measure of $5(10^5)$, a minimum electron density of 106 electrons/cm^3, and a maximum mass of $5(10^4)$ solar masses. The fainter has a maximum emission measure of $2(10^5)$, a minimum electron density of 58 electrons/cm^3, and a maximum mass of $6(10^4)$ solar masses.

Two models of the nucleus are proposed. In one, the "static nucleus" model, there are in the center about 10^9 solar masses of Population II stars in two small bodies similar to the nucleus of M31. The emitting gas is gas ejected from these stars, and the blue Population II stars excite the gas. A disk of neutral hydrogen rotates nearly as a solid body around this. In the second model, the "evolving nucleus" model, gas flows into the central parts of the nucleus, where massive young blue stars and the observed *H*II regions are formed. About one solar mass of *H*I per year flows out of the nucleus along a bar which terminates near the region of nonthermal emission. In both models the nonthermal emission is connected with magnetohydrodynamic effects associated with the galactic shear which commences in the region of the nonthermal emission. Both models are consistent with the present observations and the recent Leiden 21-cm observations of the region.

National Radio Astronomy Observatory
Greenbank, W. Va.

Drake, F. D. and Hvatum, S. *Non-thermal microwave radiation from Jupiter.*

Observations of the radio flux from Jupiter have been made at 22-cm and 68-cm wave

lengths, using the NRAO 85-foot reflector. The mean flux observed at 22 cm was about $6(10^{-26})$ (wm^{-2}) $m^{-2}(c/s)^{-1}$ during the month of May, 1959. The mean flux at 68 cm on May 26 and 27, 1959, was about $13(10^{-26})$ (wm^{-2}) $m^{-2}(c/s)^{-1}$. The blackbody disk temperatures required to produce the observed fluxes, 3000°K. and 70,000°K., approximately, are too high to be plausible. Flux measurements at 68 cm during the period July 20–30, 1959, have given a less certain flux density value of $5(10^{-26})$ (wm^{-2}) $m^{-2}(c/s)^{-1}$. The observed fluxes are combined with the data of other observers to show that Jupiter is, in fact, emitting a non-thermal spectrum with flux proportional to $\lambda^{+.2}$, approximately.

An observational search for variations in the flux is discussed. High-sensitivity monitoring of the planet at 440 mc showed no statistically significant short period variations in flux during two nights of observing. An extensive set of observations at 22 cm suggests that variations of the order of 30 per cent occur in the flux in times of the order of days. There is no statistically significant correlation between the apparent variations and planetary rotation.

It is proposed that the radiation originates as synchrotron radiation from relativistic particles trapped in the Jovian magnetic field, a situation similar to the terrestrial Van Allen belts. A Jovian field of 5 gauss and a total number of particles 10^6 times greater than in the terrestrial system will suffice to explain the observations.

National Radio Astronomy Observatory
Green Bank, W. Va.

Edelson, S., Coates, R. J., Santini, N. and McCullough, T. F. *Time relations between centimeter wavelength bursts and solar Hα flares.*

Since March 1959 the Naval Research Laboratory has been making *Hα* spectroheliograms of the sun at 6-second intervals concomitantly with centimeter solar radio observations. Flare light-curves derived from these rapid-sequence films have been compared directly with the observed flux curves of the associated radio bursts. Current measurements of time differences between the *Hα* maximum intensity and the 10-cm peak flux indicate that the events may be classified according to the 10-cm excitation level which exists before the flux peak.

In the first type, the 10-cm radio flux rises rapidly to a peak from the quiet sun level in less than 2 minutes, and always precedes the *Hα* maxima. In 60 per cent of the events of this class, the 10-cm burst peaks occur 2 to 10 seconds before the *Hα* maxima; 35 per cent have time differences of 10 to 20 seconds; and 5 per cent lead the *Hα* by 20 to 30 seconds.

In the second type, 10-cm excitation exists for more than 4 minutes before the time of burst peak flux. Five per cent of the events of this class have 10-cm peaks following the *Hα* maxima by 0 to 10 seconds, while the great majority have 10-cm peaks preceding the flare maxima with the following time distribution: 30 per cent lead by 0 to 10 seconds, 35 per cent lead by 10 to 20 seconds, 25 per cent lead by 20 to 30 seconds, and 5 per cent lead by 30 to 40 seconds. There is evidence that several events of the second type may be associated with more than one source.

U. S. Naval Research Laboratory
Washington, D. C.

Evans, John W. *Flare-associated magnetic activity in the sun.*

Observations of the longitudinal Zeeman effects in a solar active center show the variations of magnetic field strength during a period of 144 minutes on 30 April 1958, which included the development and decay of a flare of importance 1+. The measurements show that the flare crossed the neutral line of zero longitudinal field, and, although the extremities lay in regions of steep field gradients, most of the flare area was a region of low gradient. A small but pronounced S pole within the flare area developed and faded away in exact synchronism with the flare intensity. However, the large magnetic changes affected the whole field of the active center. The integrated magnetic energy of the region underwent a sharp decrease of about 16 per cent during the 14 minute rising phase of flare intensity, and an even sharper recovery to its initial value immediately after flare maximum. This behavior was shared by the large sunspot fields and the area outside the sunspots. On the assumption that the field was 5000 km deep, the energy change of the active center amounted to 4×10^{31} ergs. The *Hα* radiation of the flare during its life was about 10^{28} ergs. Thus the changes in magnetic energy probably exceed the total radiation of the flare in the Balmer and Lyman series by a considerable factor.

Sacramento Peak Observatory
Sunspot, New Mexico

Fernie, J. D., Hiltner, W. A. and Kraft, Robert P. *The Cepheid AQ Puppis, a probable member of the association II Puppis.*

Radial velocities, spectral types and *U, B, V* photometry have been obtained for the brighter members of the O-B association II Pup (L. Munch 1951*a*, 1951*b*, 1954; Schmidt 1958). These data, combined with the light and color curves and the radial velocity (Stibbs 1955) of the Cepheid AQ Pup ($P = 29.85$ days), strongly suggest that the latter is a member of the association. The result is somewhat preliminary since the color excess $E(B\text{-}V)$ is variable over the field of the association, and has an estimated uncertainty of ± 0.05. With an absolute magnitude estimated from the brighter main sequence stars (Johnson and Iriarte 1958), the following data apply to AQ Pup:

$$(B\text{-}V)^{\circ}_{\max} = +0.42 \qquad (B\text{-}V)^{\circ}_{\text{med}} = +0.80$$

$$M_{v\text{med}} = -6.1$$

The median color and period, when plotted on Sandage's (1958) theoretical HR diagram for Cepheids, also give $M_v = -6.1$. The color is in agreement with that estimated from the spectral type—intrinsic color relation for cepheids and supergiants (Kraft 1959).

This research was supported in part by Air Force Contract No. AF-19(604).

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Physics Department
University of Capetown
Capetown, South Africa and
Yerkes and McDonald Observatories
University of Chicago
Chicago, Ill.

Gaposchkin, Sergei I. *On two brightest globular clusters.*

A photometric study in two colors (red and blue) of the globular clusters ω Centauri and 47 Tucanae, has been made on plates taken with the Baker-Schmidt telescope in Bloemfontein, South Africa. Exposures were from three to sixty minutes, permitting study of magnitude, color, and position of the stars along a substantial length of the radius. The magnitude limit is about 18.5. The envisaged plan is to investigate the stars in the clusters in two perpendicular directions and to compare the population of the clusters. For ω Centauri these directions coincide with the major and minor axes. Since 47 Tucanae is practically spherical in appearance, one direction was chosen towards the major axis of the Small Magellanic Cloud. Magnitude measures are by Eichner photometer, and by a graduated scale of star images simultaneously seen by blink. The relative difference of color can also be determined directly. These two clusters, though relatively similar in extent, present the greatest contrast in four essential properties: the population of variables, the density gradient towards the center, the existence of stars of intermediate brightness, the distribution of the brightest stars together with smoothness of profile.

Harvard College Observatory
Cambridge, Mass.

Gaposchkin, Sergei I. and Teske, Richard G. *Spectrum and brightness of l_2 Carinae.*

Three dozen spectrograms were taken of l_2 Carinae, a classical Cepheid of 35-day period, by Sergei Gaposchkin during the winter of 1956–57 at Mt. Stromlo Observatory. The dispersion is about 45 Å/mm. In addition, six spectrograms were taken in the red region of the spectrum.

Since the purpose of this study was to investigate the appearance of the spectrum throughout a light cycle, visual estimates of the brightness of l_2 Car were made simultaneously with the spectrograms. These visual estimates are tied to the HPv system. It has been found that the light curve shows a secondary wave with bright maxima and minima followed several cycles later by faint maxima and minima. It appears from the spectra that the star tends to have a slightly higher luminosity at the brighter maxima than it does at the fainter maxima.

Emission cores seen in the H and K lines of *Ca*II disappear at about maximum light, though the phase of their appearance cannot be stated from the material at hand. Minimum luminosity appears to occur before minimum light; the range in spectral type is about 0.4 spectral classes.

Harvard College Observatory
Cambridge, Mass.

Gehrels, Thomas. *Polarization of the light from Moon, Mars, Venus, and NGC 7023.*

With the Wollaston photometer, described separately, the polarization of seven small lunar regions was observed at different phases and wave lengths. The results in visual light are similar to those obtained by Lyot (1929), but the wave length dependence is strong. Up to 23 per cent polarization was found in the ultraviolet for lunar maria at quarter phase.

Mars and Venus show the same wave-length dependence with strong polarization in the ultraviolet. In the ultraviolet, Mars at 33° phase has 6.7 per cent, while Venus at 59° phase has 2.4 per cent positive polarization. In visual light, the agreement with Lyot's results is nearly perfect, with Venus at 59° phase showing 1.7 per cent negative polarization.

The present program was initiated in 1956 to verify, or disprove, an explanation of lunar phase effects in terms of accreted interplanetary particles. The strong wave-length dependence of Moon, Mars, and Venus, and the peculiar polarization-reversal of Venus may indeed be explained by a partial coverage with very small accreted particles. The observed polarization of Mars and Venus is then a composite that is partly caused by suspended particles as well as by the planetary atmosphere.

Three regions of NGC 7023 were observed with wide filters at 3600, 5500, and 8300 Å; a typical region has 13, 19, and 22 per cent polarization with these filters, respectively. Particle sizes of the order of 0.5 microns, different from those for Moon, Mars, and Venus, are indicated for NGC 7023.

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Yerkes and McDonald Observatories
University of Chicago
Chicago, Ill.

Gehrels, Thomas and Teska, Thomas M. *A Wollaston photometer.*

A photometer of the McDonald Observatory was converted for interchangeable use in either *UBV* photometry, or in six-color polarization measures. The polarization is analyzed with a Wollaston prism and two multiplier phototubes by simultaneous integration. A complete series on a fairly bright object, at six position angles and in six colors, takes about 60 minutes; this requires 144 integrations as at each angle the tubes are exposed twice, namely with and without a depolarizer in the incoming beam. Neither thin clouds nor poor seeing affect the polarization measures. The effective wave lengths range from 3250 to 9900 Å. Two types of tubes are used, namely RCA 7102, having S-1 response, and RCA 7265, with multi-alkali cathode. Reductions of the observations are made with the IBM 650 of Indiana University. The internal probable errors are ±2° in position angle, larger when the polarization is very small, and ±0.1 in the percentage polarization.

Results on the main program of solar system studies are in a separate paper. As a check on this new equipment, eight strongly polarized stars were observed that occur in the lists of Hall and Mikesell and of W. A. Hiltner; in visual light the agreement is close. However, it was found that in the ultraviolet as well as in the infrared the interstellar polarization is less than in visual light. The sunlit blue sky shows approximately the same wavelength dependence. It was found that neither the 82-inch mirror nor the photometer cause depolarization in the ultraviolet; the observations and the depolarization test will be fully reported in another publication.

Astronomy Department
Indiana University
Bloomington, Ind.

Giordmaine, J. A., Alsop, L. E., Townes, C. H. and Mayer C. H. *Observations of Jupiter and Mars at 3-cm wave length.*

Radiation associated with the planet Jupiter in the wave length range 3.03 to 3.37 cm has been observed during the period April 16, 1958 to February 7, 1959. The observations were made with the U. S. Naval Research Laboratory 50-foot reflector in conjunction with a maser amplifier (Giordmaine *et al.* 1959). A total of 153 drift curves through the position of the planet was obtained.

The following are the average equivalent black body temperatures of the visible disc observed in the several wave length ranges: 3.36 ± 0.01 cm, April 16 to May 8, 1958 with the exception of April 30 to May 1, 189 ± 20°K; 3.17 ± 0.02 cm, May 24 to July 29, 1958 and January 31 to February 7, 1959, 173 ± 20°K; 3.03 cm, August 22 to September 4, 1958, 171 ± 20°K. The probable errors quoted for the black body temperatures are mainly those arising from the uncertainty in the effective

aperture of the reflector, and the relative precision of the measurements is considerably higher. There is evidence of an anomalously high temperature, approximately 268°K, on April 30 to May 1, 1958.

The observed radiation is interpreted as thermal emisssion from ammonia in the region near the top of the cloud layer. The gaseous ammonia radiates through the inversion line at 1.28 cm, pressure broadened in the presence of hydrogen and helium. Thermal radiation from lower levels in the atmosphere probably accounts for an appreciable fraction of the higher temperature radiation reported at longer wave lengths in the centimeter and decimeter region.

Radiation associated with the planet Mars was observed at 3.14 cm, on December 22, 1958. The equivalent black body temperature was 211 ± 28°K, in good agreement with previous measurements at this wavelength. Individual drift curves with peak antenna temperatures of about 0.08°K were averaged in this work.

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Columbia University
New York, N. Y. and
Radio Astronomy Branch,
U. S. Naval Research Laboratory
Washington, D. C.

Goldstein, Samuel J., Jr. *The angular size of short-lived solar radio disturbances.*

A wide-band two-element adding interferometer which accepts simultaneously the radiation in the range 105–140 Mc/sec was used to observe short-lived solar disturbances. The angular size of Type I bursts was found to be less than 1.6 minutes of arc. The average angular size of type III bursts in three clusters was 3′.2, and for four other clusters an average lower limit of 3′.3 was obtained. The theory of these measurements is explained.

Harvard College Observatory
Cambridge, Mass.

Gum, Colin S. *Some similarities in the distribution of neutral hydrogen and radio continuum sources in the galaxy.*

21-cm surveys at Leiden (Westerhout 1957) and Sydney (Kerr, Hindman and Carpenter 1957) have demonstrated the existence of a very flat layer of neutral hydrogen in the inner regions of the galaxy ($R < R_0$). In the outer regions ($R > R_0$) the hydrogen layer is systematically distorted.

Observations at various frequencies in the radio continuum show that one component (the disk component) of this radiation is strongly concentrated towards the galactic plane. Although the continuum results show only integrated effects along the line of sight, the two-dimensional distribution which is observed may be compared with that expected if the sources of the continuum radiation were distributed similarly to the hydrogen gas. The results of such comparisons for published surveys indicate that the sources are concentrated towards the same plane as the hydrogen gas in the regions $R < R_0$, and show a similarly distorted distribution for $R > R_0$. In addition, the observations of Mills, Hill and Slee (1958) suggest that the disk component radiation originates in the spiral arms delineated by the *H*-line observations.

These results imply a close physical interdependence of some type between the hydrogen gas and the radio continuum sources. Such studies may therefore help in the understanding of the mechanism of origin of the continuum emission.

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Mt. Wilson and Palomar Observatories
Pasadena, Calif.

Hamid, Salah and Nagib, Mary. *On the regressional motion of the node of the Quadrantid meteor stream.*

The Quadrantid meteor stream has been studied recently by Hawkins and Southworth. From the determinations of times of shower maxima, as observed during the last 120 years, they found that the node of the stream is regressing at the rate of 0°.6/century.

It is known that the secular perturbations of the planets on a meteor stream cause such regressional motion. The secular perturbations due to Jupiter and Earth have been computed numerically using Gauss's method. The orbital elements which were used in the computation are:

	a	e	Ω	ω	i
The stream	3.66	0.72	282°	170°	72°
Jupiter	5.202803	0.0484223	99.9	13.5	1.3
Earth	1.000000	0.016729	—	102.1	—

The Earth's effect on the motion of the stream's node is found to be almost negligible, amounting to 0°.0008/century.

Jupiter's effect, −0°.3/century, accounts for almost half the observed motion. In computing Jupiter's effect, the trapezoidal rule of mechanical quadrature was applied, the independent variable taken to be the eccentric anomaly of the stream; 144 points equally distributed with respect to the eccentric anomaly were considered in the quadrature.

As a numerical check for the small error of the quadrature, we compared two values of $[W_0 \sin u]_{00}$.

For E (eccentric anomaly)

$$0°, 5°, 10°, \cdots = -3.1097377$$

$$2°.5, 7°.5, 12°.5, \cdots = -3.1097389$$

Astronomy Department
Cairo University
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Cairo, Egypt

Harrower, G. A. *Distance and density of cosmic radio sources.*

Three different methods can be used to estimate the maximum distance reached in the survey of cosmic radio sources made by B. Y. Mills and his associates. The three results lie between one and two billion light years. Their measure of agreement supports the assumption that the extragalactic cosmic radio sources are colliding galaxies radiating about one per cent of the power emitted by the source Cygnus A. It is estimated that such collisions occur with a density of 2×10^{-25} per cubic light year, and this agrees well with the density of radio sources obtainable from Mills' survey.

The results of these calculations can be applied, as well, to the design of radio telescopes with regard to a good balance between sensitivity and resolution, and to the prediction of the number of sources which a given instrument will observe.

Queen's University
Kingston, Ont., Canada

Harwood, Margaret. Distribution of variable stars in the Scutum Cloud.

A paper on the variable Stars in the Scutum Cloud is ready for publication. It reports data on 419 stars: 354 new and 65 known variables. Spectra, identified by Dr. Victor Blanco of the Warner and Swasey Observatory, are included for 183 of the long and irregular variables.

At maximum the photographic magnitudes of the majority of the new variables range between 14.0 and 16.0; minima as faint as 18.4 have been observed. Photoelectric magnitudes of stars in the Krieger sequences, obtained by Dr. Gerald Kron in 1957 with the Crossley reflector, have enabled us to correct all magnitudes to the standard of the International North Polar Sequence.

Omitting sixteen stars which are outside of the Cloud, the types of the variables are distributed as follows:

Type	New	Known	Total
RR Lyrae	66	20	86
Cepheid	11	17	28
RV Tauri	4	3	7
L.P. range $< 2^m.5$	70	13	83
L.P. range $> 2^m.5$	31	29	60
Irregular	83	17	100
Eclipsing	43	67	110
Novae	2	5	7
RW Aurigae	0	3	3
Doubtful	28	16	44
Total	338	190	528

Plots of the distribution in galactic coordinates of the RR Lyrae and of both kinds of long-period variables show a decided concentration of each type in an area centered at $l = 353°$; $b = -6°$.

Results from plots of frequency distribution are:

1. The most frequent period of long-period variables with a range >2.5 mag. is 250 days; for stars with range <2.5 mag. the most frequent period is 125 days.

2. The maximum apparent magnitude for the long-period variables, range >2.5 mag. is 14.0.

3. The maximum median magnitude for L.P. variables, range <2.5 mag., is 15.9.

4. The mean spectral type is M5 for irregular and long-period stars which have ranges <2.5 mag. and periods <250 days; the type is M6 for stars with periods >300 days and ranges >2.5 mag.

Maria Mitchell Observatory
Nantucket, Mass.

Herget, Paul. *Partial astronomical refraction.*

The advent of artificial satellites and methods of calibrating the radio devices which observe them have given rise to the problem of determining the atmospheric refraction correction

or objects which are less than "an infinite distance" away. The true position is given by $\mathbf{P} = \mathbf{S} + R(\sec z\,\mathbf{Z} - \mathbf{S})$ where z is the zenith distance, $\mathbf{Z}$ is a unit vector directed toward the zenith, $\mathbf{S}$ is a unit vector corresponding to the uncorrected astrographic position, $\mathbf{P}$ is the unit vector representing the true direction to the object, and R is a pseudo-refraction-constant, which is a function of the height of the object above the surface of the earth.

$$R(h_n) = \frac{\sum_{0}^{n} (h_n - h_{n-1})(\mu_n - 1)}{(h_n - h_0)}$$

Cincinnati Observatory
Cincinnati, Ohio

Hodge, Paul W. *Globular clusters of the Large Magellanic Cloud.*

Globular clusters of the Large Magellanic Cloud have been identified on plates taken with the ADH Baker-Schmidt telescope of the Boyden Observatory. The series of plates employed emulsion and filter combinations that correspond to B and V colors. Twenty plates in each color cover the Cloud, giving a total surveyed area of 10° by 12.5°. The plates were exposed to a uniform limiting magnitude of about 18.5. The correcting plate was diaphragmed to eliminate vignetting.

There are about 70 objects on the plates which, in their general appearance, resemble globular clusters. Not all can be true globulars, however; some have early-type spectra and blue integrated colors. The present work involved the investigation of colors and magnitudes of the brightest stars in each cluster. The color-magnitude diagrams for the brightest stars of 35 objects show them to be globular clusters similar to those of our galaxy. They have widely differing sizes, integrated brightnesses, and degrees of concentration.

The remaining clusters have stars on the main sequence as well as in the giant region. Their color-magnitude diagrams appear to be similar, within the accuracies of the photometry, to those of open clusters in our galaxy. The most notable difference is the very great total number of stars. A number of these pseudo-globular clusters contain what appear to be ordinary classical Cepheid variables. In clusters containing more than one variable, the periods of the Cepheids are nearly equal. Periods are directly related to the magnitudes of the brightest stars in the cluster in the sense that the shorter periods are found in the clusters with the fainter stars.

Harvard College Observatory
Cambridge, Mass.

Jacchia, Luigi G. *Corpuscular radiation and the secular acceleration of satellites.*

In an earlier paper it was shown that the secular acceleration of satellites fluctuates in unison with such indices of solar activity as the 10.7-cm solar flux or the sunspot number, exhibiting the occasional 27-day periodicity associated with these data. Another more transient type of disturbance was detected in the acceleration of satellite 1958 δ1 at the time of the great geomagnetic disturbances of July 9 and September 4, 1958. Both disturbances were preceded by a flare of importance 3 on the sun, which apparently did not affect the satellite motion. The perturbations in the acceleration started only with the onset of the magnetic storms, reached their peak at the center of the storms and ended with the end of the storms. This clearly shows that the perturbing agent in the upper atmosphere was corpuscular radiation.

Satellites 1958 α and 1958 $\beta 2$ show large "diurnal" effects and for both of them the 27-day fluctuations become small or actually disappear when their perigee is in the dark hemisphere. This shows that the cause of the 27-day fluctuation must reside in variable electromagnetic radiation, probably extreme UV. An accurate evaluation of the magnitude of the diurnal effect for 1958 α and 1958 $\beta 2$ is made difficult by a large atmospheric perturbation which started around mid-August 1958 and lasted two months or more; no good explanation for such perturbation has been found so far.

Smithsonian Astrophysical Observatory
Cambridge, Mass.

Johnson, Hollis R. and Athay, R. Grant. *The excitation of chromospheric HeI lines.*

Relative intensities of singlet and triplet lines of *He*I in the solar chromosphere allow a determination of $b_n \exp[\chi_n/T_e]$, where χ_n is the ionization energy of the level n and b_n is a non-thermodynamic equilibrium factor. We have computed b_n's for values of T_e ranging from

10,000° to 50,000° for an idealized helium atom consisting of a continuum and $1S$ level and the levels $2S$, $2P$, and $n = 3$, 4 and 5 in the excited singlets and triplets.

Computed and observed values of $b_n \exp[\chi_n/T_e]$ for the triplets agree for all T_e even though b_n varies with T_e. The relative populations of the triplets are determined almost entirely by the radiative transitions, which, because of the low chromospheric opacity in the triplets, are independent of the ambient T_e.

For the singlets, however, the occupation numbers of the excited levels depend critically upon R_n, the net radiative transition rates to the ground state, which are functions of τ_0, the chromospheric opacity in the first resonance line. Thus, both T_e and τ_0 are parameters of the calculations, with τ_0, in turn, being a function of T_e and n_e. The electron density, n_e, may be estimated from the absolute line intensities. In order to relate R_n to τ_0, we use the source-function computations of Jefferies and Thomas (1959).

Computed values of $b_n \exp[\chi_n/T_e]$ and τ_0 for the singlets agree satisfactorily with the empirical $b_n \exp[\chi_n/T_e]$ for $T_e \approx 40{,}000°$–$50{,}000°$. Uncertainties in atomic constants and R_n may permit a T_e as low as 30,000°, but certainly not as low as 25,000°. At chromospheric densities, helium becomes predominantly *He*II at $T_e \approx 20{,}000$, and predominantly *He*III at $T_e \approx 55{,}000°$. Chromospheric helium is, therefore, predominantly *He*II as suggested earlier by Athay and Menzel (1956).

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National Bureau of Standards and
High Altitude Observatory
Boulder, Colorado

Keenan, Philip C. *Absolute magnitude of the Mira variable X Monocerotis.*

The sharpness of the stellar absorption lines in the spectra of the Mira variables allows their interstellar D-lines to be observed if their peculiar radial velocities exceed 30 to 40 km/sec. X Mon is a particularly favorable case, since it has $V_r' = 142$ km/sec and is located at galactic latitude $-1°$. The observations of X Mon (type M3e at maximum, $P = 155$ days) were made near maximum light on a scale of 15 Å/mm with the coudé spectrograph of the Mount Wilson 100-inch telescope. Because of blending of interstellar D_1 with *Ni* 5892, only D_2 could be measured, giving W = 0.26 Å and $V' = +10$ km/s for the interstellar component.

Four A- or B-type comparison stars within of the variable all proved to have strong interstellar lines than those of the variabl This made necessary an extrapolation whic reduced the accuracy of the determination distance. The estimated values for X Mon a $M_v = -0.7$, $d = 350$ pc.

This luminosity is lower than the mean valu generally estimated from the motions of th Mira variables of shorter period. The differenc is probably real, for classification of its spectru in the blue indicates that X Mon is one of th least luminous of the Mira variables.

In another respect also, X Mon is atypica for its mean visual amplitude is only 1.8 magn tudes. Nevertheless, it should probably b retained among the Mira variables, for X Mo is normal in the strength of its Balmer emissio and in the degree of weakening of the stella absorption lines in comparison to ordinar giants.

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Perkins Observato
Delaware, Oh

Kerr, Frank J. *The integrated brightness approac to 21-cm galactic studies.*

The interpretation of 21-cm observations i the region of theg alactic disk has so far bee based on a consideration of the detailed structur of line profiles. This work has led to representa tions of the spiral structure and the three dimensional shape of the Galaxy, but th interpretation is dependent on assumption about the rotational and random motions a various distances from the galactic center.

A number of interesting results can be ob tained from a study of the "integrated lin brightness" for each direction in the sky, withou the need to derive a distance scale from a assumed rotation curve. The picture which i obtained from the profile details must then b compatible with the integrated brightness re sults. Also, comparisons can be made directl with the distribution of the continuum radiatio at various wave lengths.

Two determinations can be made of th apparent direction of the galactic center, th first from the variation of integrated brightnes

with longitude, and the second from a comparison between the positive and negative portions of the integrated profiles. These indicate that the mass and velocity distributions of the neutral hydrogen are both approximately symmetrical about the direction for the center which is obtained from other evidence. Further, the integrated brightness results lead to a more reliable rotational velocity model, which is based on a larger region of the Galaxy than has been used for earlier models, and involves only the assumption that the Galaxy is rotationally symmetrical when viewed on a large scale.

C.S.I.R.O. Radiophysics Laboratory
Sydney, N.S.W., Australia

Koch, Robert H. *Photoelectric photometry of R Canis Majoris.*

Yellow, blue, and violet photoelectric light curves of R CMa were obtained at the Steward Observatory. At each wave length the maximum following primary eclipse does not show the expected ellipticity and reflection effects. Within eclipse a common solution for 0.8 limb darkening fits the observations satisfactorily. This solution differs from three previous ones in a manner which gives a spuriously large relative size for the hot star. The physical mechanism causing this discrepancy is unknown. The remaining elements are much the same as those found earlier and can be considered well-determined.

Flower and Cook Observatory
University of Pennsylvania
Philadelphia, Pa.

Kozai, Yoshihide. *On the motion of a close earth satellite.*

Perturbations of six orbital elements have been derived as functions of mean orbital elements over all the period and a time, with no assumption about an order of magnitude of an eccentricity and an inclination. The assumptions employed were that the density distribution of the earth is symmetrical with respect to the axis of rotation, that the coefficient of the second harmonic of potential is a small quantity of the first order and that the coefficients of the third and fourth harmonics are of the second order. My results include periodic perturbations of the first order and secular variations up to the second order.

However, the solutions have some singularities for an orbit whose eccentricity or inclination is smaller than a quantity of the first order, so this case is treated in a different way.

A theorem is demonstrated that there are no long-periodic terms of at least the first order in the expression of the semi-major axis by using Delaunay's canonical elements.

Smithsonian Astrophysical Observatory
Cambridge, Mass.

Kraft, Robert P. *Intrinsic colors for cepheids and late-type supergiants derived from interference filter photometry of the G-band.*

Using narrow-band interference filters, an index Γ, which measures the strength of the G-band, has been obtained for a number of Cepheids and for supergiants from F2 to K0. A good correlation is found between Γ and spectral type from F5 to G4. Measurements of Γ have also been made during the entire cycle of the Cepheid U Sgr, and at isolated phases of EV Sct and δ Cep; intrinsic colors are known for these Cepheids because of companions or membership in an open cluster (Irwin 1958, Arp 1958, Gascoigne and Eggen 1957). It is therefore, possible to correlate Γ with $(B\text{-}V)$. The variability of spectra type for Cepheids during a cycle permits the derivation of intrinsic colors for class Ib and II stars from F5 to G4.

At F5 Ib, the $(B\text{-}V)$ colors of Cepheids agree with that of α Per (Harris 1956). Color excesses and distances are given for a number of summer Cepheids.

This work was supported by Air Force Contract No. AF19(604).

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Yerkes and McDonald Observatories
University of Chicago
Chicago, Ill.

Krogdahl, W. S. *Analogies between self-excited systems and intrinsic variables.*

The simplest self-excited systems of the Van der Pol type may be classified according to their respective excitation and damping parameters. A sequence of their limit cycle solutions displays properties which exhibit qualitative analogues of the properties of the sequence of intrinsic variables arranged in order of period.

University of Kentucky
Lexington, Kentucky

Kuiper, Gerard P. and Miczaika, G. R. *A new observatory in Chile.*

The establishment of a new observatory in the vicinity of Santiago de Chile has become possible as a result of concurrent interests by the Universities of Chile, Chicago and Texas; and the Geophysics Research Directorate of the Air Force Cambridge Research Center. An agreement between the three Universities has been signed which covers the construction of the Observatory building and access road by the University of Chile; the initial staffing and operation of the Observatory by the Universities of Chicago and Texas, in close coordination with the McDonald Observatory; and a student- and faculty-exchange program between the Universities of Chile and Chicago. A contract between the Air Force Cambridge Research Center and the University of Chicago covers the erection of a 60-inch reflector at the Chile observatory. The primary mirror will have an aperture ratio of f/5, but no arrangements will be made for use of the prime focus; this avoids the necessity of using a bridge and a fairly large dome. Instead, two Cassegrain foci will be used, one f/8 for photography and one f/13.5 for photoelectric and spectrographic work. A preliminary site survey was made in March 1959, and systematic site tests were begun in May to permit a final decision between three or four sites selected. The design of the telescope is well under way; completion of the installation is expected in December, 1961.

Yerkes and McDonald Observatories
University of Chicago
Chicago, Ill. and
Geophysics Research Directorate
Air Force Cambridge Research Center
Bedford, Mass.

Lichtenstein, Pearl R. *Calculation of cosmic radio noise absorption produced by pulses of ionizing radiation.*

The time variation of excess electron density in the D-layer of the ionosphere, which results from pulses of ionizing radiation associated with solar flares, has been calculated. It is assumed that the change in electron density due to the pulse is small compared with the undisturbed value, a condition which is true only for very small events. At low frequencies, such as 18 Mc/s, the absorption is shown to be directly proportional to the excess electron density.

Comparison of calculated absorption curves with sudden cosmic noise absorptions observed at Rensselaer shows: 1) the peak absorption is delayed with respect to the peak of the ionizing pulse; and 2) the value of the recombination coefficient is of order 3×10^{-6} cm^3/sec, a higher value than is obtained from other types of measurements.

Rensselaer Polytechnic Institute
Troy, N. Y.

Lilley, Edward and Brouwer, Dirk. *The solar parallax and the hydrogen line.*

The use of absorption lines in the spectra of discrete sources as frequency standards is examined. Such lines appear to be particularly attractive for a measurement of the solar parallax. Produced by the hyperfine transition $F = 0 \rightarrow F = 1$, the absorption lines are the sharpest features known in 21 cm research.

An interstellar *HI* cloud which produces the absorption line, has some velocity with respect to the sun. By measuring the exact frequency of the line on two occasions about six months apart, one can eliminate the cloud's constant motion and obtain a value of the earth's orbital velocity. The velocity measurements permit one to compute the solar parallax. This is a standard method with stellar radial velocities which, because of optical limitations, has not been successful in improving knowledge of the solar parallax. However, by shifting the experiment into the radio domain, sufficiently precise Doppler measurements are possible.

A number of calculations have been performed to investigate the accuracy of the hydrogen line-solar parallax experiment. We find that it is a "time-limited" problem, and that two basic quantities compete to limit the precision of a single measurement. The quantities are:

(1) The natural rate, $d(\Delta\nu)/dt$, at which the absorption line shifts frequency due to the orbital and rotational motions of the earth.
(2) The minimum time, τ, during which a given radio telescope and receiver combination, working on a particular source, can achieve a measurement accuracy of δf cycles.

The expressions for (1) and (2) are:

$$\frac{d(\Delta\nu)}{dt} = \frac{\nu_0 k}{c} \cos\delta \cos\phi \cos H \frac{dH}{dt} \qquad (1)$$

$$\tau = \frac{2}{B}\left(\frac{s}{N}\right)^2\left(\frac{\Delta f}{4T_s\delta f}\right)^2 (T_s + T_R)^2, \qquad (2)$$

where the symbols have their usual definitions in spherical and radio astronomy.

The total annual hydrogen line Doppler shift for a source on the ecliptic is of the order 3×10^5 cycles. Thus the accuracy with which the parallax may be determined becomes $\delta f/3 \times 10^5$. A new hydrogen line radiometer is being designed and developed, funded by the National Aeronautics and Space Administration. The performance goal for the radiometer is $\delta f = 1$ cycle, leading to an accuracy goal of about one part in 3×10^5 for the solar parallax. The solar parallax observational program will extend over several years and will be conducted at the Naval Research Laboratory and at Agassiz Station of Harvard College Observatory.

Harvard College Observatory
Cambridge, Mass. and
Yale University Observatory
New Haven, Conn.

Mayer, C. H. and Sloanaker, R. M. *Polarization of the 10-cm radiation from the Crab Nebula and other sources.*

A search was made for linearly-polarized components of the 10.2 cm radiation from the radio sources Cassiopeia-A (IAU 23N5A), Taurus-A, the Crab Nebula (IAU 05N2A), Cygnus-A (IAU 19N4A), Virgo-A (IAU 12N1A), and M17 (IAU 18S1A) using the 84-foot reflector at the NRL Maryland Point Observatory. Only the radiation from the Crab Nebula showed characteristics which could be interpreted as due to a plane-polarized component of the radiation.

The horn-type feed antenna at the focus of the reflector was rotated continuously about its axis by a motor drive causing the plane of polarization accepted by the antenna to rotate. After correction for instrumental effects, no plane-polarized component greater than 1 per cent was detected in the radiation of Cas-A, Cyg-A, or M17. The lower intensity of the radiation from Virgo-A did not allow as good precision of measurement, but an upper limit of about 3 per cent can be placed on a linearly-polarized component. The Crab Nebula showed a distinctly different result from the other sources which can be interpreted as a linearly-polarized component of about 3 per cent of the total radiation with a position angle for the electric vector of about 135 degrees.

The sources Cas-A, Cyg-A, and the Crab Nebula were measured at two other wave lengths as well, 11.3 cm and 11.5 cm. The results were similar at the three wave lengths indicating that there is little Faraday rotation along the path between the Crab Nebula and the earth. This conclusion is supported by the close agreement between these measurements of position angle at 11.5, 11.3, and 10.2 cm with those previously measured at 9.6 cm (Kuz'min and Udal'tsov 1959), at 3.15 cm (Mayer, McCullough, and Sloanaker 1957), and the average position angle measured optically (Oort and Walraven 1956).

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Radio Astronomy Branch
U. S. Naval Research Laboratory
Washington, D. C.

McClain, Edward F. *A test for non-thermal radiation from Jupiter at a wave length of 21 cm.*

Measurements of the radiation temperature of Jupiter have been made in the vicinity of 3 centimeter wave length by Mayer, McCullough, and Sloanaker (1958), Drake and Ewen (1958), and Alsop, Giordmaine, Mayer and Townes (1958). These measurements are all in reasonable agreement with measurements made in the infrared. The consensus of opinion therefore has been that the source of this radiation is probably thermal. Later, McClain and Sloanaker (1959) reported temperatures of approximately 600°K from Jupiter at a wave length of 10 cm. These measurements were slightly suggestive of rather rapid variations in the measured temperature as a function of time. Drake reported informally at the May 1959 URSI meeting on temperatures in the range of 2000 to 3000 degrees Kelvin at a wave length of 21 cm and suggested that this radiation might arise from Van Allen belts surrounding the planet. Stanley (1959) has measured temperatures as high as 5000°K to 10,000°K at 32 cm.

This paper deals with a series of measurements at 1430.00 Mc made on 28 days during a one-month period from May 14 to June 18, 1959. An attempt has been made to correlate what may be a variable temperature with the density

of solar particles as indicated by magnetic storms on the earth, with the 10 cm solar index and with System I and System II rotation. No correlation has been found with the 10 cm solar index. In the case of solar particles, the fact that Jupiter was in opposition at the time of the measurements would lead one to expect that particles causing magnetic storms on the earth following a flare on the sun might reasonably be expected to arrive in the vicinity of Jupiter a few days later (first suggested by Drake). No strong correlation of this sort has been noted in these measurements. However, there is a slight suggestion of elevated temperatures following an importance 3+ flare on May 10 and the intense aurora of May 11 and 12.

Each of the 28 daily measures is the average of 4 or 5 drift curves taken over a period of 2 hours. When plotted against time, these 28 measurements are highly suggestive of a cyclical variation. An attempt has been made to correlate this data with System I and System II rotation. In the case of System I no significant correlation was observed but in the case of System II an elevated temperature has been noted at a longitude of 200°. This enhancement of about 30 per cent appears to lie between 175° and 225°. While rather significant when subjected to a statistical test, the amount of data is limited and this conclusion should be considered tentative. Correlation might actually be more pronounced with a system differing from both Systems I and II but sufficient data is not available at the time this is written. The mean temperature obtained from all data is 2496°K with a standard deviation of 450°.

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Radio Astronomy Branch
U. S. Naval Research Laboratory
Washington, D. C.

McDonald, Jean K. *Radial velocities of stars in the Praesepe Cluster.*

Radial velocities have been determined from 200 spectrograms of 66 stars with apparent magnitude ≤ 9.2, in the region of the Praesepe Cluster. The linear dispersions at $H\gamma$ were principally 51 Å/mm and 90 Å/mm.

The observation program was planned in 1952 with the advice of R. J. Trumpler, who kindly provided a list of the velocities he had determined for stars of this cluster. His observations had been limited to stars within 1° of the cluster center, and our program was revised accordingly to concentrate principally on the zone 1° to 2.5° from the center.

Within the 2.5° circle, there are 97 stars with magnitudes ≤ 9.2, of which 47 lying within 1° of the center were included in Trumpler's list. Of these 47 stars, 19 were included in my observation program and the mean difference in the radial velocities, in the sense Trumpler minus McDonald, is +1.2 km/sec.

Of the 50 observed stars that lie within the 1° to 2.5° zone, 34 are believed to be non-members, 6 from parallax and proper motion data and 28 from radial-velocity determinations, 4 show variable velocity, and the remaining 12 stars, listed in the table, are undoubtedly cluster members. The three marked with asterisks have been identified previously as cluster members by H. L. Johnson from color-magnitude studies.

The mean velocity given by Trumpler for 57 cluster stars within 1° of the center, brighter than magnitude 10.3 was +32.9 km/sec, which agrees with the mean velocity of the 12 stars in the Table.

	m_v	Type	Velocity
H.D. 72358	8.4	F5	+29.7 km/sec
72779*	6.6	G0	33.9
72846*	8.3	A2	32.2
73045*	8.5	A0	27.1
73555	8.3	F8	34.4
73620	9.1	F0	35.4
74587	9.1	A5	32.7
74656	8.1	A0	31.6
74718	8.6	A5	32.1
74720	8.2	A2	35.3
74780	9.0	A5	36.3
74814	9.2	K0	33.6

Mean velocity +32.9 ± 0.50 km/sec.

Dominion Astrophysical Observatory
Royal Oak, B. C., Canada

McLaughlin, Dean B. *The Be spectrum variable π Aquarii.*

π Aquarii is one of the best examples of large variations of the "V/R type," in which the relative strengths of apparently double hydrogen emission lines vary in a cyclic manner. Large shifts of the emissions and the central absorption lines accompany these changes. Strongest redward emissions occur with greatest negative

shifts of both emissions and central absorptions. Both outer edges of the emission lines shift in the sense stated, so that the absorption remains nearly central in the structure. This behavior appears to be characteristic of all the well-observed stars of this type, such as 25 Orionis (Dodson 1936), β^1 Monocerotis (McLaughlin 1951), and HD 20336 (McLaughlin 1958).

Prior to 1924, the emission components of π Aquarii were equal, and velocities essentially constant. Then conspicuous changes began. The first cycle probably occupied four or five years (unless very rapid changes occurred in 1927 when observations were not obtained). Later cycles were two or three years in length. Velocity amplitudes reached 150 km/sec for central absorption, and 200 km/sec for edges of $H\beta$ emission. Amplitudes of both V/R and velocity were much reduced and the emission somewhat weak from 1935 to 1943. Then followed a stage of extreme weakness or absence of emission lines until 1950. After that time the emissions strengthened greatly, with nearly equal components and velocities near the mean value, -10 km/sec.

A new phase of activity began in 1956. By July, 1959, about three-fourths of a cycle had been completed and the amplitude appeared to be increasing rapidly.

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University of Michigan Observatory
Ann Arbor, Michigan

McNamara, D. H., Hansen, Kimball and Walton, W. *Stellar rotation and the Beta Canis Majoris stars.*

A statistical investigation of all the B1 and B2 stars (luminosity class III-V) north of declination —30° and brighter than magnitude 5.6 has revealed that 23 stars have apparent rotational velocities ($V \sin i$) in the same range as the β CMa variable stars. Of these 23 stars, 11 are known to be β CMa variable stars. According to the difference between the observed $V \sin i$ and true distribution V of rotational velocities derived by Slettebak, this is approximately the number we would expect to be β CMa variables if all B1 and B2 stars (proper luminosity class) with rotational velocities below a certain critical value pulsate and show β CMa characteristics. The 12 other stars, therefore, are probably stars of large rotation with their axis of rotation approximately in the line of sight. The sin i factor is near zero and hence the measured values of $V \sin i$ are small.

Brigham Young University
Provo, Utah

McVittie, G. C. *The cosmical constant and the curvature of space.*

The average density of matter in the universe given by Oort at the 1958 Solvay Conference was $\rho_0 = 3.1 \times 10^{-31}$ gr/cm^3 with a distance-scale such that the Hubble "constant" H is 75 km/sec/mpc. The retardation of the expansion of the universe seems to be fairly well established, at least as to sign, if not as to magnitude. If h_1 is H expressed in (seconds)$^{-1}$ and h_2 is the acceleration parameter, then the available data on red-shifts give $h_2 = -q_0 h_1^2$ where q_0 lies between 1.5 and 5. Einstein's field equations for a uniform model universe, combined with these data, then lead to the following conclusions: (a) the cosmical constant has the negative value $-(3q_0 - f_0)h_1^2$; (b) the space-curvature is also negative, the contemporary radius of curvature being $(q_0 + 1 - f_0)^{-1/2} c h_1^{-1}$. Here f_0 is the ratio $4\pi G\rho_0/h_1^2$ and is equal to 0.044 if $H = 75$ km/sec/mpc and to 0.088 is $H = 150$ km/sec/mpc. A negative cosmical constant means that, in addition to gravitation, there exists in the universe a second force which prevents the galaxies from flying apart. A zero cosmical constant dispenses with this additional force and thus all the responsibility for the retardation is thrown onto gravitation. The observed density of matter is insufficient to produce the retardation and this is the reason why model universes with zero cosmical constant always predict densities that are too high by a factor of between fifty and two hundred. A negative curvature, of course, implies that space is hyperbolic and therefore open and of infinite extent.

University of Illinois Observatory
Urbana, Ill.

Meinel, A. B. *Ratio spectra for G8 stars.*

The ratio spectrometer measures the ratio of intensity from a narrow wave length region to that from a broad region, the relative widths of the two slits being 50 and 250Å, respectively. The narrow band is centered within the wide wave length region. The relative placement of the two slits remains constant as the spectrum is scanned.

It is advantageous to employ a ratio spec-

trometer for several reasons. Firstly, the gross energy distribution curve of the star is flattened, approaching a straight line upon which the spectrum is displayed. Secondly, the ratio is independent of intensity fluctuations arising from seeing or from guiding errors. Thirdly, it is insensitive to variable extinction caused by the terrestrial atmosphere and interstellar absorption.

The spectrometer has been used to explore the possibility of extending the techniques of spectral classification developed by Stromgren. A program for the observation of MK standard stars has been started at Kitt Peak using one of the 16-inch Cassegrain telescopes.

An examination of tracings for luminosity and age characteristics immediately discloses interesting features in the later type stars. The illustrations show the range of effects noted in G8 stars. The most variable feature is the 4140 *CN* band when compared to adjacent features, or to the 3880 *CN* band. These bands are well known classification features and this illustration is made to indicate that the ratio spectrometer may be a promising tool for spectral classification.

Since fixed wave lengths are not employed, large radial velocities will not affect the method; hence, it may prove useful in classifying composite objects such as globular clusters and galaxies. In fact, the method may also be useful in determining radial velocities for distant nebulae simply by noting the wavelength shift of the entire pattern with respect to the spectrometer calibration scale.

This instrument will be a part of the instrumentation available to visiting astronomers with both the 16-inch and 36-inch telescopes.

Kitt Peak National Observatory
Tucson, Arizona

Millman, Peter M. and Halliday, Ian. *The near-infrared spectrum of meteors.*

Photographic records of meteor spectra in the infrared were first secured in 1950 (Millman 1953) and by the end of 1958, seven Perseid meteors had been photographed at Canadian stations on fast Eastman infrared emulsions. Two infrared spectra photographed at the Springhill Meteor Observatory on August 12, 1958 confirm features previously identified in earlier spectra showing less detail.

The better of the two Springhill spectra is of a Perseid with a visual magnitude -5, and shows a detail of 47 atomic emission lines, 33 in the visible region and 14 in the wave length range 7000–9000Å. Using the multiplet table by Moore (1945) all the infrared lines have been satisfactorily identified with four nitrogen multiplets, *N*I (1), (2), (3), (8), two oxygen multiplets *O*I (1), (4), and a multiplet of ionized calcium *Ca*II (2). The visible region of the spectrum shows lines of *H*I, *Na*I, *Mg*I, *Mg*II, *Si*I, *Si*II, *Ca*I, *Ca*II, *Fe*I, *Fe*II and corresponds to the normal spectrum for bright Perseid meteors.

The meteor was recorded on both high and low power radars working at 32 Mc/s, and produced an echo that lasted for over 200 seconds. The visual persistent train had a duration of 30 seconds.

Heights for this meteor were determined by combining the photographic position with the radar range data. The photographed trail extended from a height of 104 km to 79 km with a bright burst at 84 km. The first feature to appear in the spectrum at the beginning of the trail was the neutral oxygen multiplet at 7774Å. The lines of the ionized elements gained steadily in relative strength along the trail, reaching peak relative intensity at the burst, where *Ca*II was the strongest feature.

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National Research Council
Ottawa, Ont., Canada and
Dominion Observatory
Ottawa, Ont., Canada

Morton, Donald C. *Evolutionary mass exchange in close binary systems.*

Crawford and Kopal have found many eclipsing systems with the primary or more massive component near the main sequence and the secondary filling its lobe of the Roche limit, while there is a conspicuous absence of systems in the inverse state. It has been suggested that the primary expands first, according to the usual picture of stellar evolution, but when it reaches the Roche limit, mass is transferred to the secondary until it becomes the primary, leaving the new secondary filling its lobe. This paper describes investigations to show that this exchange happens fast enough so that there is a high probability that it escapes observation.

Plotting Roche limits of typical systems on an HR diagram shows that most components can reach their limits only in the Hertzsprung gap where normal evolution is so fast that very few stars are found in this phase at any time. If the components are fairly close and if the mass ratio is near unity, a star can reach its limit just before the end of the early-evolutionary phase. To study this case the radius of a stellar model is calculated for increasing amounts of mass removed from the outer layers. The original model is based essentially on Kushwaha's 10 $M_\odot$ inhomogeneous ones. For the adiabatic case when hydrostatic but not thermal equilibrium is established after some mass is lost, the radius decreases considerably showing that the process is stable on a pulsation time scale. For a star that has settled to thermal equilibrium, the radius decreases slightly as mass is lost to a minimum about 7 $M_\odot$, then expands beyond the original radius to a maximum about 3.5 $M_\odot$. and finally decreases rapidly. The shrinking of the primary lobe caused by the mass transfer compensates the initial decrease so that the process occurs on a Kelvin time scale. Stability returns after the roles of primary and secondary are interchanged.

Princeton University Observatory
Princeton, N. J.

Oke, J. B. *The distribution of energy in the spectrum of RR Lyrae.*

The photoelectric spectrum-scanning instrument at Mount Wilson has been used to measure the absolute energy distribution in the spectrum of RR Lyrae as a function of phase. The measurements were made at a time when the amplitude of the light curve was small. Since the resolution of the instrument is only 5Å the observed continuum does not generally correspond to the true continuum because of line absorption. The relationship between the observed low-resolution continuum and the true continuum has, however, been determined by the analysis of high dispersion coudé spectrograms.

A comparison of the observed energy distribution at various phases with fluxes computed from model atmospheres yields effective temperatures and effective gravities. The range in temperature is from 6000°K to 7000°K. By combining the effective temperatures and the observed monochromatic light curves it is possible to determine the relative radii at different phases. The resulting displacement curve agrees only roughly with that derived from the integration of the radial-velocity curve. Consequently one cannot determine the absolute radius and luminosity of RR Lyrae with high accuracy.

Mt. Wilson and Palomar Observatories
Pasadena, Calif.

Petrie, R. M. *Spectroscopic observations of faint B stars.*

The extension of the Victoria observations of B stars is now virtually completed and the main features of the program may be given. The observations will supply radial velocities, spectral types and absolute magnitudes of stars largely in the apparent magnitude range 7.6 to 9.0 and mostly between spectral types O8 and B6. The program has been brought to its present stage with the collaboration of J. A. Pearce and substantial assistance from a number of colleagues.

Observations have been made with a single-prism slit spectrograph yielding a linear dispersion, at $H\gamma$, of 51Å/mm. The spectrograms are calibrated for spectrophotometric measures. Stellar radial velocities, and those of interstellar calcium, have been measured. Equivalent widths of K and $H\gamma$ have been measured for about one-half of the stars. Revised spectral types will be assigned in the near future.

The program contains 560 stars, mostly of types B5 and earlier; some 2250 spectrograms have been obtained. The apparent-magnitude distribution is as follows:

Mag. interval	No.	Mag. interval	No.
<7.5	38	8.51 to 8.70	95
7.51 to 7.70	55	8.71 to 8.90	43
7.71 to 7.90	72	8.91 to 9.10	26
7.91 to 8.10	87	9.11 to 9.30	8
8.11 to 8.30	49	9.31 to 9.50	2
8.31 to 8.50	85		

A preliminary study of the radial velocities suggests a high percentage of stars of variable velocity. The frequency curve of probable errors shows a sharp rise from zero to a peak at about ±2.7 km/sec, followed by a gradual decline toward larger values. One may deduce from the shape of the curve that approximately 50 per cent of the stars are varying in radial velocity.

Dominion Astrophysical Observatory
Royal Oak, B. C., Canada

Popper, Daniel M. *The strange case of RS Canum Venaticorum.*

New spectrographic observations of the eclipsing binary, RS CVn show that the radii are 8 per cent and the masses 22 per cent smaller than previous evaluations. The K type subgiant is slightly more massive than the smaller F type star and does not appear to fill the critical zero-velocity surface. In these respects this system differs from most of those of similar kind.

The light curve has long been known to show persistent, but not constant, asymmetries, both within and outside of eclipse. Comparison of photoelectric observations made in 1956 and in 1959 shows the light of the K star at primary minimum to have increased by 0.3 mag. with no or only a slight change of color. There was no corresponding increase in the light outside of minimum. The light of the K star apparently varies intrinsically both with time and over its surface. The asymmetry outside of minimum is found by color measurements also to be caused by the K subgiant. This persistent asymmetry could be caused by a slight pulsation with the same period as the orbital motion. This system also undergoes changes of period of a unique character. Nearly continuous photometric observations of high precision are needed to determine the behavior of the star.

The spectrograms outside of eclipse show no evident peculiarities except for variable $H\alpha$ emission associated with the K star. The lines of the F star are sharp, hence the designation "n" of Joy's classification is not suitable.

University of California
Los Angeles, Calif.

Rabe, Eugene. *The orbit of (1011) Laodamia and the mass of Mars.*

The recently improved orbit of the minor planet (1011) Laodamia (Rabe 1956) reveals a remarkable relationship to the orbit of Mars. The trajectories interlock near to the ascending node of Laodamia on Mars, and to the aphelion of Mars. The orbits approach to 0.04 a.u., yet the approach is so asymptotic that the distance between the two curves is of the order of 0.1 a.u. for orbital arcs of nearly 90°, between the approximate heliocentric longitudes of 96° and 181°. The orbits deviate by less than 0.05 a.u. between the longitudes 158° and 169°. The closeness of actual approaches depends on the difference of the longitudes. In consequence of the near commensurability of the mean motions of Mars and Laodamia in the ratio 1.97:1, any close approaches occur in series of successive passages. The subsequent approaches of September 1957 and March 1961 amount to 0.10 a.u. each. They are preceded by an approach to 0.36 a.u. in January 1954, and followed by approaches to 0.14 and 0.36 a.u. in September 1964 and June 1968, respectively.

If the Mars perturbations of Laodamia are integrated from a zero epoch in 1959, between the two closest approaches to 0.10 a.u., then in the backward integration the longitude perturbations exceed $-1000''$ already in 1941 (the discovery opposition is 1924). The perturbations will increase even more rapidly in the forward integration, through the three approaches to 0.10, 0.14 and 0.36 a.u. In perihelion oppositions these perturbations can be observed at geocentric distances of roughly 0.6 a.u. The planet has been observed in 5 oppositions 1924–57, mostly near perihelion. Observers with powerful instruments are urged especially to observe this relatively faint object as extensively as possible, because undoubtedly the mass of Mars can be determined from the motion of (1011) Laodamia to a very considerable degree of accuracy.

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University of Cincinnati Observatory
Cincinnati, Ohio

Roman, Nancy Grace. *Planets of other suns.*

As seen from the distance of Alpha Centauri, Jupiter, at its maximum apparent separation from the sun, $3''.94$, would be a star of $23^m.4$ (assuming that its phase function is that of Venus); it would brighten to a maximum of $22^m.0$ at exterior conjunction. For Venus, Earth, Saturn, the maximum brightnesses and separations are, respectively: $22^m.5$ and $0''.55$, $23^m.4$ and $0''.76$, and $22^m.7$ and $7''.23$ (with the rings at moderate inclination).

Thus, a similar planetary system around Alpha Centauri would be within the reach of our largest telescopes and our current photoelectric techniques if our terrestrial atmosphere did not limit our resolution. At a separation of more than $2''$, it does not seem to be a serious problem to get rid of the light of the primary in the absence of an atmosphere.

The following instrumental set up is a possible solution: Let a 20″ diaphragm, at the focal plane of a large telescope, be bisected by a highly polished razor. Let a 45° mirror on one side reflect the light into a photomultiplier and let the light on the other side go into a light trap. Any departure from a constant signal as the position angle of the multiplier is varied would be due to either a planetary companion or a distant star. A repetition of the experiment several months later should decide this question.

Other stars from which a member of our solar system would be at least as bright as $25^{m}.0$ and as far as $0''.75$ from the primary include: β Hyi, Sirius, Procyon, Altair, Fomalhaut, Vega, β Gem, and Arcturus.

A telescope on an artificial earth satellite can probably not provide either the size of instrument or the necessary guidance accuracy for the long periods of observing time required for this experiment but an observatory on the moon would be ideally situated.

Office of Space Sciences
National Aeronautics and Space Administration
Washington, D. C.

Sandage, Allan and Wallerstein, George. *The color-magnitude diagram of the nuclear globular cluster NGC 6356 compared with halo clusters.*

NGC 6356 is representative of a group of globular clusters located in the vicinity of the galactic center which have strong spectral lines. A color-magnitude diagram of the cluster has been determined to $V = 19.4$ and $B = 20.3$ from plates and a photoelectric sequence obtained at the 200-inch telescope.

The diagram shows a strong giant branch extending from $V = 15.3$, $B\text{-}V = 2.2$ to $V = 17.5$, $B\text{-}V = 1.2$; but the slope of this giant branch is considerably less than that of a normal globular cluster. There appears to be a short horizontal branch and a poorly defined sub-giant branch. The horizontal branch extends to $B\text{-}V = 0.8$; but no bluer stars are present. The magnitude difference between the horizontal branch and the giant branch is only 2.4 mag. as compared with the usual value of about 3 mag.

From colors and spectra of foreground B and A stars the reddening is at least $E_{B-V} = 0.5$ and may be greater. The reddening estimate is uncertain because there are no RR Lyrae stars in the cluster.

Comparison of the color-magnitude diagram of NGC 6356 with other clusters has been made by fitting the horizontal branches. This comparison shows that the giant branch of NGC 6356 is fainter than the giant branches of typical globular clusters such as M13 and M92, but is brighter than the giant branch of the old galactic cluster M67. Thus NGC 6356 is intermediate between M13 (which shows a metal deficiency of a factor of about 20) and M67 whose stars seem to have normal metallic lines.

This result, combined with the number of stars on the giant branch, is consistent with Morgan's description of the spectrum as being giant K with *CN* present in absorption.

Mt. Wilson and Palomar Observatories
Pasadena, California and
University of California
Berkeley, California

Searle, Leonard. *A spectrophotometric study of R Coronae Borealis.*

High-dispersion spectra of the hydrogen-poor, carbon-rich supergiant variable R Coronae Borealis, obtained at maximum light, have been quantitatively compared with similar spectra of the standard supergiant δ Canis Majoris. The equivalent widths of 200 unblended lines in the wave length region λλ4000–4700 have been measured and a curve of growth abundance comparison carried through.

The carbon to iron ratio is found to be 25 times greater in R CrB than in δ CMa. The carbon to hydrogen ratio in R CrB is found to be about 40. Lines of nitrogen and oxygen do not fall in the region studied. Among the metals there is no clear evidence for abundance anomalies exceeding a factor of two. In particular the abundance of the rare-earth elements relative to iron is the same in R CrB and the standard star.

Quantitative agreement between predicted and measured equivalent widths of the carbon lines is obtained with the hypothesis that the predominant opacity source in R CrB is the photoionization of neutral carbon.

Precise measures of the blended molecular bands in R CrB are not possible, but rough intensity estimates give reason for believing that the ratio of carbon to nitrogen must be greater in R CrB than in stars of solar composition.

If it is true that the composition of the atmospheric material of R CrB differs from solar composition only in the abundances of carbon, hydrogen and helium then the composition parameters of R CrB are $X = 0.00014$, $Y = 0.92$, $Z_c = 0.07$. If on the other hand nitrogen and

oxygen are overabundant in R CrB by the same factor as carbon we obtain $X = 0.00014$, $Y = 0.66$, $Z_{cno} = 0.33$.

David Dunlap Observatory
University of Toronto
Richmond Hill, Ont., Canada

Sloanaker, Russell M. *Apparent temperature of Jupiter at a wave length of 10 cm.*

Thirty-three measurements of the apparent temperature of Jupiter were made between June 10 and August 20, 1958 at wave lengths of 10.2 and 10.3 centimeters using the Naval Research Laboratory, 84-foot diameter, paraboloidal antenna. Each measurement consisted of the point by point average of from 4 to 8 right-ascension scans of the antenna beam thru the position of Jupiter at the sidereal rate. The measured apparent blackbody temperatures ranged from 300°K to 1010°K about a mean of 640°K ± 85°K estimated standard error. The high value of apparent temperature was unexpected, because it was higher by factors of 3 to 4 than apparent temperatures previously measured in the centimeter wave length region of the spectrum, at wave lengths between 3.15 cm and 3.75 cm, which were in reasonable agreement with temperatures measured in the infra-red.

The present measurements give a roughly normal distribution of apparent temperature with a standard deviation of 190°K. On the basis of the estimated measurement errors, the expected standard deviation is about 145°K, which is in reasonably good agreement with the observed scatter, but does not preclude the possibility of a variable component in the intensity of the radiation. The measured temperatures show no long-time trends over the 71 day measurement interval, but show a suggestion of a cyclical variation of about 30 per cent correlated with a rotation rate between 40 seconds and 2 minutes longer than the rotation period of System II.

U. S. Naval Research Laboratory
Washington, D. C.

Strand, K. Aa. *The astrometric orbit of Epsilon Aurigae.*

An attempt to determine the astrometric orbit of ϵ Aurigae was based on 124 plates with multiple exposures taken on 59 nights between 1926 and 1958 with the Yerkes 40-inch refractor.

A period of 27.08 years and an eccentricity of 0.33 were adopted in the solution for the parallax and orbital elements.

The parallax was found to be $0''.006 \pm 0''.003$ (*p.e.*) as compared with the spectrophotometric parallax of $0''.001$ based upon the brighter component being a supergiant F2 star with an absolute magnitude of -7.0.

The two orbital elements of special interest are the orbital inclination and the semi-major axis which were found to be 72° and $0''.014 \pm 0''.004$ (*p.e.*) respectively.

The inclination obtained in this study agrees with the value generally accepted to explain a grazing eclipse. The latter is most consistent with the spectrophotometric data.

With the above value of the inclination, the spectroscopic orbit yields a semi-major axis of 2.1×10^9 km or 14 a.u. This value, compared with the astrometric semi-major axis, gives a parallax of $0''.001$.

It is concluded that even a substantial increase in the astrometric data will lead only to very approximate values for the orbital elements.

U. S. Naval Observatory
Washington, D. C.

Tuve, M. A., Ford, W. K., Jr., Hall, J. S. and Baum, W. A. *Speed gains obtained with a cascaded image converter.*

A 30-fold gain in speed over conventional direct photography has been obtained with an R.C.A. two-stage cascaded image converter attached to the Cassegrain focus of the Naval Observatory 40-inch reflector at Flagstaff. Under the operating conditions adopted, the fog level due to dark emission inside the converter was much less than that due to the natural night-sky background at an optical focal ratio of $f/6.8$. If the sky background had been absent, the dark emission alone would have limited the exposure time to about 20 minutes, which would have been equivalent to a 10-hour exposure with conventional photography.

Observations of close double stars having separations as small as $0''.7$ have been attempted with the converter attached to the Lowell 24-inch refractor. A 16-mm motion picture camera was mounted behind the converter in order to record very short exposures in rapid succession. It was thereby possible to catch occasional images which were less blurred by "seeing" than they would have been under the same conditions with the longer exposures required by conven-

tional photography. The effective exposure times with the converter and motion picture camera were 1/20th second or less. Since the dark emission of the converter was unimportant for such short exposures, the operating potential could be increased enough to yield speed gains of about 100-fold.

The cascaded converter is an extremely simple device to use. It requires no specially prepared plates, no home-made photocathodes, no external vacuum system, and no liquid-air traps. It requires only a voltage supply and a fast camera lens.

This work is being carried out under the Carnegie Institution with the support of the National Science Foundation.

Carnegie Institution of Washington
Washington, D. C.,
Lowell Observatory
Flagstaff, Ariz. and
Mt. Wilson and Palomar Observatories
Pasadena, California

Underhill, Anne B. *The hydrogen lines of 9 Sagittae, O7f.*

Very little quantitative data on the shapes and strengths of lines in O-type spectra exist. This paper presents equivalent widths and line profiles of the Balmer lines of hydrogen in the spectrum of 9 Sagittae, O7f. The observations were obtained with the 72-inch telescope and cassegrain spectrograph during the years 1950 to 1958. The resolution is sufficient that the apparent profiles require no correction for instrumental effects. No secular changes in this spectrum were observed except in the emission feature at $H\alpha$.

The $H\alpha$ emission is variable in intensity being stronger in 1957 than in 1951 or 1953, the only years in which observations of this line were obtained. The total extent of the emission is $\pm$ 12Å, corresponding to a velocity displacement of $\pm$ 540 km/sec. The emission is due to hydrogen only since the $4n$ series of *He*II which blends with the Balmer lines to about $H10$ is entirely in absorption. Any broad absorption feature due to *He*II and *H* that might exist at $H\alpha$ is entirely filled in with emission.

The absorption profile at $H\beta$ has a somewhat peculiar, shallow shape. It is interpreted as a broad strong absorption due to *He*II and *H* which has partially been filled in with emission from hydrogen.

The profiles of the lines $H\gamma$ to $H16$ are entirely in absorption. The *He*II lines blend on the violet side causing an unsymmetric profile. The Balmer series terminates at $H16$ which is clearly present as a moderately strong line blended with *O*III and *He*I. There is no line of comparable strength near the position of $H17$ or of any higher member of the Balmer series. This truncation of the series indicates that Stark effect is the major broadening agent of the hydrogen lines. A comparison of the apparent wings of $H10$ to $H14$ with those of $H\gamma$, $H\delta$, and $H\epsilon$ leads to the conclusion that the apparent continuum at $\lambda < 3900$Å is depressed by overlapping of the wings of the hydrogen lines even though the ultra-violet hydrogen lines appear to be well separated. According to the Teller-Inglis formula the electron density is 2×10^{14}.

Dominion Astrophysical Observatory
Victoria, B. C., Canada

van den Bergh, S. *The luminosity classification of galaxies.*

The degree to which spiral structure is developed in galaxies is strongly correlated with absolute luminosity. This correlation is in the sense that the brightest galaxies have the most highly developed spiral arms.

A two-parameter classification system has been developed which assigns a type and a luminosity class to each galaxy. By means of this classification system the absolute magnitudes of Sb, Sc and Ir galaxies may be estimated with an accuracy of about half a magnitude on the prints of the Palomar Sky Survey.

The appearance of many spiral galaxies which are members of physical pairs or dense clusters differs from that of isolated spirals of the same type and luminosity. Sb galaxies which are members of pairs or clusters often have fuzzier spiral arms than isolated galaxies of the same type. The appearance of such galaxies on the Sky Survey blue prints is quite similar to the appearance of isolated Sb galaxies on the red prints. This suggests that the luminosity function of star creation may be deficient in bright OB stars in many Sb galaxies which are members of close pairs or dense clusters. Sc spirals in clusters tend to have patchier spiral arms than isolated Sc galaxies.

The differences between isolated and cluster galaxies may be due to the after-effects of tidal interactions. There appears to be a distinct possibility that such galaxies which have suffered

interactions form a sequence intermediate between normal spirals and highly flattened objects of type So.

David Dunlap Observatory
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Van Herk, G. *Expanding motions in N30.*

The N30 proper motions in declination for the eight stars of spectral class A in the Lacerta region show a change with declination amounting to + 3.6 ± 0.6 (*p.e.*) in units of 0″.001 per year per degree declination. This is several times the rate of expansion of + 0.86 found by Blaauw and W. W. Morgan (1953) for the B stars in this region. These expansions could be catalogue effects. The stars in the zone + 36°.5 to + 52°.5 show the expansion rates given in the second column of the table below. As a check, the stars between + 0°.0 and + 15°.0 were treated in the same manner, and their rates of expansion are entered in the fifth column of the table.

Sp.	Rate	*n*	Rate	*n*
A	+0.67	95	+0.82	135
F	+0.92	46	+0.53	99
G	+0.54	35	−0.77	67
K & M	+0.40	116	−0.12	210
Mean	+0.63 ± 0.08		+0.12	

The motions were corrected for the effect of solar motion before the rates were computed. The parallaxes were taken from *Ap. J.* **116**, 123, 1952, or *Ap. J.* **81**, 187, 1935, or estimated from the apparent visual magnitudes and the spectral classification, the latter being taken from *Mt. Wilson Obs. Papers* **8**, 1953 or from the Harvard classification. In cases of doubt the decision was based on an empirical relation between apparent proper motion and parallax. All proper motions exceeding 0″.075 were excluded. As the boundaries of the first-mentioned zone lie close to the zenith of Washington and the average zenith of the European meridian circles, it is possible that discontinuities in meridian circle declinations near the zenith are responsible for the expansions in this zone which are absent from the lower zone. This would explain the criticism of Woolley and Eggen (1958) of Blaauw and Morgan's expansion.

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Woolley, R. v. d. Riet and Eggen, O. J. 1958, *Observatory* **78**, 149.

U. S. Naval Observatory
Washington, D. C.

Violett, T. and Rense, W. A. *Far ultraviolet spectrum of the Sun.*

Solar ultraviolet spectrograms were obtained from Aerobee-Hi rocket flights on 4 June, 1958 and 30 March, 1959. In each case the instrument was a grazing-incidence grating spectrograph whose speed was increased by a suitably designed toroidal mirror placed in front of the slit at grazing incidence. The instruments were pointed at the sun by a biaxial pointing control. Zenith heights attained by the rockets were 220 km and 204 km, respectively. About 150 emission lines in the range 84–1216Å were found to appear on spectrograms from both flights. About 200 other possible lines were present.

The wave lengths of the lines have been measured in most cases to within an accuracy of 0.5Å. Rough visual estimates of the relative intensities of the lines were made, along with a quantitative estimate of the intensity of the 304Å *He*II resonance line for several altitudes of the rockets. The *He*II line was by far the most intense line other than *H* Lα, and possibly could be more intense than the latter outside the earth's atmosphere.

Identification of about 60 lines was made. The neutral and ionized atoms, *H*, *He*, *O*, *C*, *N*, and *Si*, dominate. The *O*VI line at 150Å was present. A rather intense line at 84Å possibly could be due to *Ne*VIII. The high intensity of the scattered light background prevented the detection of any continuum in this region. A program for the systematic identification of the remaining lines has been launched.

The research reported in this paper has been sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.

Physics Department
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Wentzel, Donat G. *Equilibria of magnetic stars.*

A variational method has recently been developed by Chandrasekhar which permits the calculation of equilibrium configurations of magnetic stars. The magnetic and velocity fields and also the shape of the boundary surface may be evaluated even when the magnetic and kinetic energies are comparable to the gravitational potential energy of the star. The theory is restricted to an infinitely conducting fluid of uniform

density under conditions of axisymmetry. The equilibria depend on an infinite set of integrals of motion, and some of the simpler cases have been investigated in detail.

A magnetic field which lies completely in meridional planes deforms the star into a doughnut-like object, but when the fluid is in self-gravitational equilibrium, the boundary surface is always an ellipsoid of revolution. The eccentricity and the form of the magnetic fields may be evaluated. A special case is that of the force-free fields. The effect of surface forces may be included explicitly.

If the fluid rotates as a solid body without magnetic fields, the well known results on Maclaurin ellipsoids follow from the variational method. In the presence of magnetic fields the treatment may be generalized to include different modes of isorotation.

If a certain relation between the integrals of motion is satisfied, there is equipartition between magnetic and kinetic energy everywhere in the fluid at equilibrium.

When the virial theorem is not satisfied, instability appears to manifest itself primarily in a decrease in density rather than large changes in boundary shape.

Physics Department
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Chicago, Ill.

Wilson, Raymond H., Jr. *Geomagnetic rotational retardation of satellite 1959 α1 (Vanguard II).*

Observations on satellite 1959 α1 (Vanguard II) of the frequency of radio signal maxima show, over the three weeks of battery life, an exponential decay in spin-rate with a relaxation time of 72 days. Its rotational damping is thus three times more rapid than that observed on 1958 β2 (Vanguard I) (Wilson 1959). This ratio is to be expected if the effects on both satellites are due to energy dissipation by geomagnetic induction of eddy currents in the satellite, since, for the rough approximation of similar solid spheres, the damping rate would be inversely proportional to density (Wilson 1956), and the mean density of Vanguard II is less than one-third that of Vanguard I.

A precise analysis of electromagnetic couples, taking into account the various shapes and materials of conducting parts of Vanguard II, seems to show quantitative confirmation of the terrestrial dipole field found by a similar analysis (Wilson 1959) of Vanguard I.

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National Aeronautics and Space Administration
Washington, D. C.

Wright, F. W., Jacchia, L. G. and Boehm, B. W. *Photographic Lyrid meteors.*

The present analysis gives the mean radiant path of the photographic Lyrids. The mean radiant of the stream has a daily motion of 16′ eastward and 10′ northward with respect to the equator in the interval from April 7 through April 23 U.T. The mean deviation of an extended meteor trail from the mean moving radiant is ± 23′. This is in general agreement with the relation between meteor stream-widths and radiant deviations which was derived for eleven other photographic streams.

At the time of maximum activity of the Lyrids, on April 21 and 22, U.T., the sun is only six degrees from the extended mean radiant path. This is in good agreement with a recent observation by one of us that the sun is never more than a few degrees from the extended mean radiant path of a meteor shower near the time of maximum activity for the shower.

Harvard College Observatory
Cambridge, Mass.

Wright, K. O. *Line intensities in the spectrum of Arcturus.*

In continuation of a study of line intensities in the spectra of K-type stars (Wright 1950) additional high-dispersion (3.2Å/mm) spectra of α Bootis, K2 IIIp, have been obtained in the region λλ 4000–4900. Regions of little or no absorption, adopted as the continuum, usually agree with those shown by Hiltner and Williams (1946). Line identifications, though not their intensities, usually follow those given by Miss Davis (1947) for β Pegasi; molecular absorption, though present, is small and can be neglected in many regions of the spectrum. Even with a narrow slit, the profiles of most lines are defined by the instrument; this is also shown by comparison with Mount Wilson coudé spectra (2.9Å/mm) which show greater resolution and where the lines are sharper. Strong *Fe*I lines show

well-developed wings, but lines of moderate intensity also seem to show traces of wings.

Curves of growth have been constructed for several elements; for high-excitation *Fe*I lines, *f*-values recently measured in emission by Crosswhite (1958) have been used. The curves of growth tend to confirm the adopted level of the continuum since lines in the λ 4000 region fit the same curves as those of longer wave length. Most lines of *Fe*I, *V*I and *Ti*I fit a single curve of growth which corresponds to a velocity of 2.7 km/sec and a damping factor, log $2\alpha = -2.3$ for Hunger's (1956) Milne-Eddington model for pure absorption.

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Dominion Astrophysical Observatory
Royal Oak, B. C., Canada

Zirin, H. and Tandberg-Hanssen, E. *Spectroscopic classification of prominences.*

Spectra obtained at Climax of an active limb region, March 23, 1958, show clearly the spectroscopic difference between active and quiescent prominences, as a large nearby filament also appears on the spectra. The following differences appear: the ionized metallic lines, which appear strongly in the quiescent, disappear or are greatly weakened in the active. The line *He*I 4713 is about 8 times as intense as *He*II 4686 in the quiescent, but is only one-half as intense as 4686 in the active prominence. The spectrum of the quiescent is essentially that of the chromosphere at 1500 km. The lines in the active prominence (which was a loop type) are much broader than those in the quiescent and the width at half-intensity of λ4686 is considerably greater than that of 4713, as already found by us in other cases.

On the basis of these and other spectra, the gas in the solar atmosphere exhibits physical properties which fall into four well-defined classes. These, with criteria, are:

I. Low chromosphere (*He*I 4713 < *Ti*II 4572).
II. Chromosphere above 1500 km; Quiescent prominences (filaments); Ascending prominences (disparitions brusques): *He*I 4713 > *Ti*II 4572 4713 ≫ *He*II 4686; *He*I 4026 ~ *Sr*II 4077.
III. Loop prominences; Coronal rain; Flares; Flare sprays; Surges: 4713 ≲ 4686; 4026 >4077.
IV. Corona.

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THE ESCAPE OF STARS FROM CLUSTERS. IV. THE RETARDATION OF ESCAPING STARS

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Abstract. By a simple application of the concept of time of relaxation, it is shown that encounters by escaping stars increase the effective time of relaxation by the time required for an escaping star to leave the cluster. The effect is negligible for large clusters but decreases the escape rate by a third for the smallest clusters.

The rate at which stars escape from an isolated cluster is generally estimated by calculating the rate at which encounters endow individual stars with the escape velocity. However, a star that has the escape velocity will not necessarily escape; for further encounters may slow it down before it passes the limits of the cluster. Chandrasekhar has called attention to this effect (1942, p. 209) and suggested that it may be significant. The present paper is an attempt to determine to what extent further encounters decrease the rate of escape of stars.

The method is based on the original Ambartsumian-Spitzer approximation, in which each time of relaxation sees the escape of those stars that in a Maxwellian distribution have more than the escape velocity. Let the cluster contain n_1 "bound" stars, having less than the escape velocity, and n_2 "free" stars, which have acquired the escape velocity but have not yet had time to pass beyond the confines of the cluster. Now let us suppose that in a time equal to the time of relaxation, τ, the stars of *each* group acquire a Maxwellian velocity distribution. The work of Spitzer and Härm (1958) shows that this assumption gives nearly the correct rate of transfer of bound stars to the free group. For the free stars the validity of the assumption is less certain, but it seems likely to hold for free stars just as well as for fast-moving bound stars that have almost the same velocity.

The rate of change of the number of bound stars will then be

$$\frac{dn_1}{dt} = -\frac{K}{\tau} n_1 + \frac{1 - K}{\tau} n_2, \qquad (1)$$

where K is the fraction of stars to which the Maxwellian distribution assigns more than the escape velocity. The bound group is gradually depleted, but the number of free stars should change very little. Very soon after its origin a cluster should settle down into a steady state in which bound stars become free at just the same rate as free stars leave. Thus n_2 will remain nearly constant. The gradual depletion of the cluster will cause a slow decrease in n_2, but over as short a time as τ the change will be inappreciable.

The stars taken from n_1 are of course added to n_2, and this gain must be balanced by the loss of those stars that escape completely from the cluster. If a star that has acquired the escape velocity takes a time θ to escape, then the condition for constancy of n_2 is

$$\frac{K}{\tau} n_1 - \frac{1 - K}{\tau} n_2 = \frac{1}{\theta} n_2, \qquad (2)$$

or

$$n_2 = \frac{K\theta}{\tau + (1 - K)\theta} n_1. \qquad (3)$$

With this, (1) now becomes

$$\frac{1}{n_1}\frac{dn_1}{dt} = -\frac{K}{\tau + (1 - K)\theta}.$$

Since K is so small, it is nearly as accurate to write

$$\frac{1}{n_1}\frac{dn_1}{dt} = -\frac{K}{\tau + \theta}. \qquad (4)$$

Thus the retardation of escaping stars decreases the rate of escape of stars, increasing the effective value of τ by the escape time θ.

The time of relaxation of a star cluster is an ill-defined quantity, since conditions vary so much from one part of the cluster to another. However, Paper I of this series (King 1958) shows that for a cluster whose density distribution is that of a polytrope of index 5, the over-all escape rate may be found by using the effective value

$$\tau = 0.526 \sqrt{\frac{nR^3}{Gm}} \frac{1}{\ln (n/2^{3/2})}. \qquad (5)$$

R is the radius containing half the mass in projection, n is the total number of stars in the cluster, m is the mass of an individual star, and

G is the constant of gravitation. However, Spitzer and Härm have since pointed out (1958) that the factor $\ln (n/2^{3/2})$ is based on a wrong choice of cut-off for the impact parameter and should be replaced by $3/2 \ln (n/2)$. The effective time of relaxation is therefore

$$\tau = 0.35 \sqrt{\frac{nR^3}{Gm}} \frac{1}{\ln (n/2)} . \qquad (6)$$

The time of escape θ is also ill defined. It will depend on where the star is when it acquires the escape velocity, in what direction it is traveling, and where we set the limits of the cluster. A reasonable average, however, is the time required to move one cluster radius, for a star having the average escape velocity. But the average escape velocity is given by

$$\overline{v_e^2} = 4\overline{v^2} \qquad (7)$$

(Chandrasekhar 1942, p. 206), while for a polytrope of index 5 the virial theorem gives

$$\overline{v^2} = 0.29 \frac{Gnm}{R} . \qquad (8)$$

Thus with

$$\theta = \frac{R}{\sqrt{\overline{v_e^2}}} , \qquad (9)$$

(6), (7), and (8) give

$$\frac{\theta}{\tau} = \frac{2.65 \ln (n/2)}{n} , \qquad (10)$$

and the rate of escape of stars is reduced by a factor $1 + \theta/\tau$.

Table I gives $1 + \theta/\tau$ for several values of n, the number of stars in the cluster. The retardation of escaping stars has a negligible effect in the richest clusters, while in the poorest aggregations that would be recognized as clusters the escape rate is reduced by about a third.

TABLE I. FACTOR BY WHICH THE ESCAPE RATE IS REDUCED

n	20	50	100	200	500	1000
$1 + \theta/\tau$	1.31	1.17	1.10	1.06	1.03	1.016

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NOTICE

Visiting Scientist Programs at the National Radio Astronomy Observatory. The National Radio Astronomy Observatory was established by the National Science Foundation to make available to scientists from any institution facilities for research in radio astronomy. The Observatory now has in operation an 85-ft. diameter radio telescope, together with receivers for work at various wavelengths in the range 75-cm to 3.75-cm. Miscellaneous other facilities are also available. The facilities of the Observatory are open to any competent scientist with a program of work in radio astronomy, regardless of institutional affiliation.

A scientist with a program he wishes to undertake at the National Radio Astronomy Observatory may apply by letter to the Director, National Radio Astronomy Observatory, P. O. Box 2, Green Bank, West Virginia. The letter should contain a description of the program of work to be carried out, including a statement of the objects to be investigated, their positions and expected flux densities or antenna temperatures, the receivers to be used, any additional or special equipment that will be needed, and the investigator's estimate of the time required for the program.

The Observatory invites inquiries from any scientist interested in radio astronomy, concerning the opportunities and facilities available at the National Radio Astronomy Observatory. Previous experience in the techniques of radio astronomy is not necessary. Information about the equipment available, the types of arrangements that may be made, etc., may be obtained from the Director on request.

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